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Oskarshamn site investigation

Complete hydrochemical characterisation in KSH01A

Results from four investigated sections, 156.5–167.0, 245.0–261.6, 586.0–596.7 and 548.0–565.4 metres

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December 2004

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Abstract

Complete chemical characterisation has been conducted in four sections, 156.5–167.0, 245.0–261.6, 586.0–596.7 and 548.0–565.4 m of borehole KSH01A. This is the most extensive chemical investigation method performed in core drilled boreholes. The Complete chemical characterisation entails pumping, measurements on-line and regular water sampling for chemical analyses in isolated borehole sections during a time period of approximately three weeks per section and at a flow rate between 50 and 200 mL/min.

The results obtained from the investigation in sections 156.5–167.0, 245.0–261.6 and 548.0–565.4 m includes on-line measurements of redox potential, pH, dissolved oxygen, electric conductivity and water temperature in the borehole section as well as chemical analyses of major constituents, trace components and isotopes. Furthermore, gas content and composition, inorganic colloids as well as humic and fulvic acids in the groundwater were investigated. In section 245.0–261.1 the fractionation of humic and fulvic acids were cancelled since there were no flow at the time for the fractionation. Section 586.0–596.7 were interrupted due to high flushing water content (36%) and repairs of the down hole equipment after approximately three weeks of pumping.

The flushing water content in the samples should not exceed 1% to be considered representative for the groundwater of the fracture zone. This condition was not met in any of the investigated sections. The flushing water content in the final sample in each section was 3% (156.5–167.0 m), 8% (245.0–261.1 m) and 11% (548.0–565.4 m). The chloride concentration increased with depth and was in the final water sample approximately 5,600 mg/L in section 156.5–167.0 m, 6,300 mg/L in section 245.0–261.1 m and 8,800 mg/L in section 548.0–565.4 m. Stable redox potential measurements are reported from the three sections 156.5–167.0, 245.0–261.1 and 548.0–565.4 m. The redox electrodes stabilised at approximately –257, –160, –173 mV respectively. The reducing conditions in the groundwater of the three sections were also verified by the presence of ferrous iron Fe(+II) at relatively high concentrations. The content of inorganic colloids was low or nonexistent and the organic constituents were present mainly as fulvic acids and possibly other low molecular weight organic acids (citric acid, oxalic acid, etc).

Sammanfattning

Fullständig kemikarakterisering har utförts i fyra sektioner i borrhål KSH01A, sektionerna 156,5–167,0 m, 245,0–261,6 m, 586,0–596,7 m och 548,0–565,4 m. Detta är den mest omfattande kemiska undersökningsmetoden för kärnborrhål. Fullständig kemikarakterisering innebär pumpning, mätning on-line och regelbunden vattenprovtagning för kemiska analyser i avgränsade borrhålssektioner under ett en tidsperiod av cirka tre veckor och ett pumpflöde på mellan 50 och 200 mL/min.

Resultaten som erhölls från den fullständiga kemikaraktäriseringen av sektionerna 156,5–167,0 m 245,0–261,6 m och 548,0–565,4 m omfattar mätningar on-line av redoxpotential, pH, löst syre, elektrisk konduktivitet och vattentemperatur i borrhålssektionen till lika kemiska analyser av huvudkomponenter, spårelement och isotoper. Vidare undersöktes gasmängd och sammansättning, oorganiska kolloider samt humus- och fulvosyror i grundvattnet. I sektion 245,0–261,1 m ställdes fraktioneringen av humus- och fulvosyror in då det inte var något vattenflöde vid tidpunkten för provtagningen. Sektion 586,0–596,7 ställdes in efter en pumpperiod på cirka tre veckor på grund av hög spolvattenhalt (36%) och reparation av utrustningen.

Spolvattenhalten i ett vattenprov bör inte överstiga 1% för att anses vara representativt för grundvattnet i den undersökta sprickzonen. De undersökta sektionerna hade alla en spolvattenhalt över det representativa värdet. Spolvattenhalten i det sista provet taget från varje sektion var 3% (156,5–167,0 m), 8% (245,0–261,1 m) och 11% (548,0–565,4 m). Kloridkoncentrationen ökade med djupet i borrhålet och var i det sista vattenprovet ungefär 5 600 mg/L i sektion 156,5–167,0 m, 6 300 mg/L i sektion 245,0–261,1 m och 8 800 mg/L i sektion 548,0–565,4 m. Stabila redoxpotentialmätningar rapporterades för de tre sektionerna 156,5–167,0 m, 245,0–261,1 m och 548,0–565,4 m. Redoxelektroderna stabiliserade sig vid cirka –257 mV, –160 mV respektive –173 mV. De reducerande förhållanden i grundvattnet i dessa sektioner verifierades också av närvaron av tvåvärt järn i relativt höga koncentrationer. Förekomsten av oorganiska kolloider var mycket låg eller obefintlig och de organiska komponenterna förekom huvudsakligen som fulvosyror eller eventuellt andra lågmolekylära organiska syror (citronsyra, oxalsyra etc).

Contents

1 Introduction

This document reports performance of and results from the activity ”Complete hydrochemical characterisation” in the cored borehole KSH01A performed within the site investigation at Oskarshamn /1/. The work was conducted according to the activity plan AP PS 400-02-33 (SKB internal controlling document) which refer to the method description SKB MD 430.017-01 (SKB internal controlling document). The data is reported to SICADA in field note no. 56, 66, 69 and 112 for sections 156.5–167.0, 245.0–261.6, 586.0–596.7, and 548.0–565.4 m respectively.

The report presents groundwater chemistry data from four borehole sections:

- 156.5–167.0 m.
- 245.0–261.6 m.
- 586.0–596.7 m. The measurements were interrupted due to high flushing water content in the section.
- 548.0–565.4 m.

The data were obtained during March 2003–September 2003.

1.1 The cored borehole KSH01A

Borehole KSH01A is a deep telescopic borehole drilled at the site investigations in the Simpevarp subarea, Oskarshamn. The borehole is of the so called SKB chemical type, according to method description for core drilling, MD 620.003 (SKB internal controlling document). A chemical type borehole implies that cleaning procedures of all downhole equipment are used in the borehole during and after drilling, according to level 2 in the cleaning instructions in MD 600.004 (SKB internal controlling document). The location of the borehole and the flushing water well HSH03 is presented in Figure 1-1.

The borehole section 0–100.24 m is percussion drilled, with the internal diameter 200 mm, whereas section 100–1,003 m is core drilled with a diameter of 76 mm, Table 1-1 /2/.

Table 1-1. Borehole information for KSH01A and the flushing water well HSH03.

Activity	Length (m)	Diameter (mm)	Comment
Percussion drilling KSH01A	0–100.24	200	/2/
Core drilling KSH01A	100.24–1,003	76	/2/
Percussion drilling HSH03	201.00	–	/3/

Core drilling of a 1,000 m long borehole requires at least 1,000 m^3 flushing water. The concentration of uranine in the supply well HSH03 is 160 µg/L /3/.

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Figure 1-1. *Locations of the core borehole KSH01A and the flushing water well, percussion borehole HSH03.*

1.2 Previous investigations in KSH01A

KSH01A is a SKB chemistry type of core borehole. The investigations carried out in the borehole have special requirements on purity. The more equipment that is used in the borehole, the greater is the risk of contamination and thereby also effects on the in situ microbiological conditions. The activities/investigations performed in KSH01A prior to the Complete hydrochemical characterisation are listed in Table 1-2.

Table 1-2. Activities performed in borehole KSH01A prior to the chemistry campaign.

Event	Borehole section (m)	Stop date	Comment
Hydrochemical logging	1–1,000	2003-01-29	/4/
BIPS logging	101–998	2003-03-22	/5/, /6/
Geophysical logging	0–1,003	2003-02-15	/5/, /7/
Differential flow logging	100–1,000	2003-03-02	/8/

2 Objective and scope

“Complete hydrochemical characterisation” is an extensive chemical investigation method performed in core drilled boreholes and is carried out in order to obtain as much information as possible about the groundwater chemical conditions in individual water bearing fractures or local fracture zones. Considerable effort is put into obtaining representative samples from a limited rock volume. Careful pumping and continuous control of the pressure in the sampled borehole section, as well as above the section, is maintained in order to minimise the risk of mixing with water from other fracture systems.

The water analysis programme is carried out according to SKB class 2, class 4 and class 5 (including all options). In addition, pH, redox potential (Eh) and water temperature are measured in a downhole flow-through cell as well as at the surface. Surface measurements include also electric conductivity and dissolved oxygen. Furthermore, in-situ samples are collected in the borehole section: a) to determine gas contents and composition, b) for microbe content and characterisation, and c) for determination of colloid content and composition. The in situ samples maintain the pressure of the borehole section when lifted to the surface. Also fractionation of humic and fulvic acids as well as inorganic species is performed to obtain information about the size distribution in the water. In addition, enrichment of humic and fulvic acids is carried out in order to determine $\partial^{13}C$ and pmC (percent modern carbon).

3 Equipment

3.1 The mobile field laboratory

The mobile field laboratories used by SKB for water sampling and measurements in deep cored boreholes include a hose unit, a laboratory unit, downhole equipment (the equipment that is used in the borehole section) and a measurement system, Chemmac[ω] (borehole Chemmac and surface Chemmac).

The mobile units used for the investigation of the four sections in KSH01A consisted of the hose unit S2 and borehole Chemmac, the laboratory unit L2 and an unit for computer work (MYC 2), including the surface Chemmac, Figure 3-1. The equipment is presented schematically in Figure 3-2. Technical details of the equipment is documented in SKB MD 434.004, 434.005, 434.006, 434.007 and SKB MD 433.018 (SKB internal controlling documents).

The downhole equipment allows measurement and sampling in situ in the borehole section. These samples maintain the pressure from the borehole section when lifted to the surface and are used for gas analyses, microbe investigations and colloid filtration. Some special equipment for more complex sampling activities (humic and fulvic acids and colloids) have also been used.

Figure 3-1. *The mobile units at KSH01A; from left L2, MYC 2 and S2. Photo: Karl-Göran Nederfeldt.*

[ω] Chemmac-surface and borehole Chemmac. A measurement system with communication system and measurement application. The measurement application in surface Chemmac includes a device for measurement of pH, Eh, oxygen, electric conductivity and temperature, the corresponding application for borehole Chemmac includes measurement of pH, Eh and temperature. However, the configuration of electrodes in surface and borehole Chemmac can be varied between the sections.

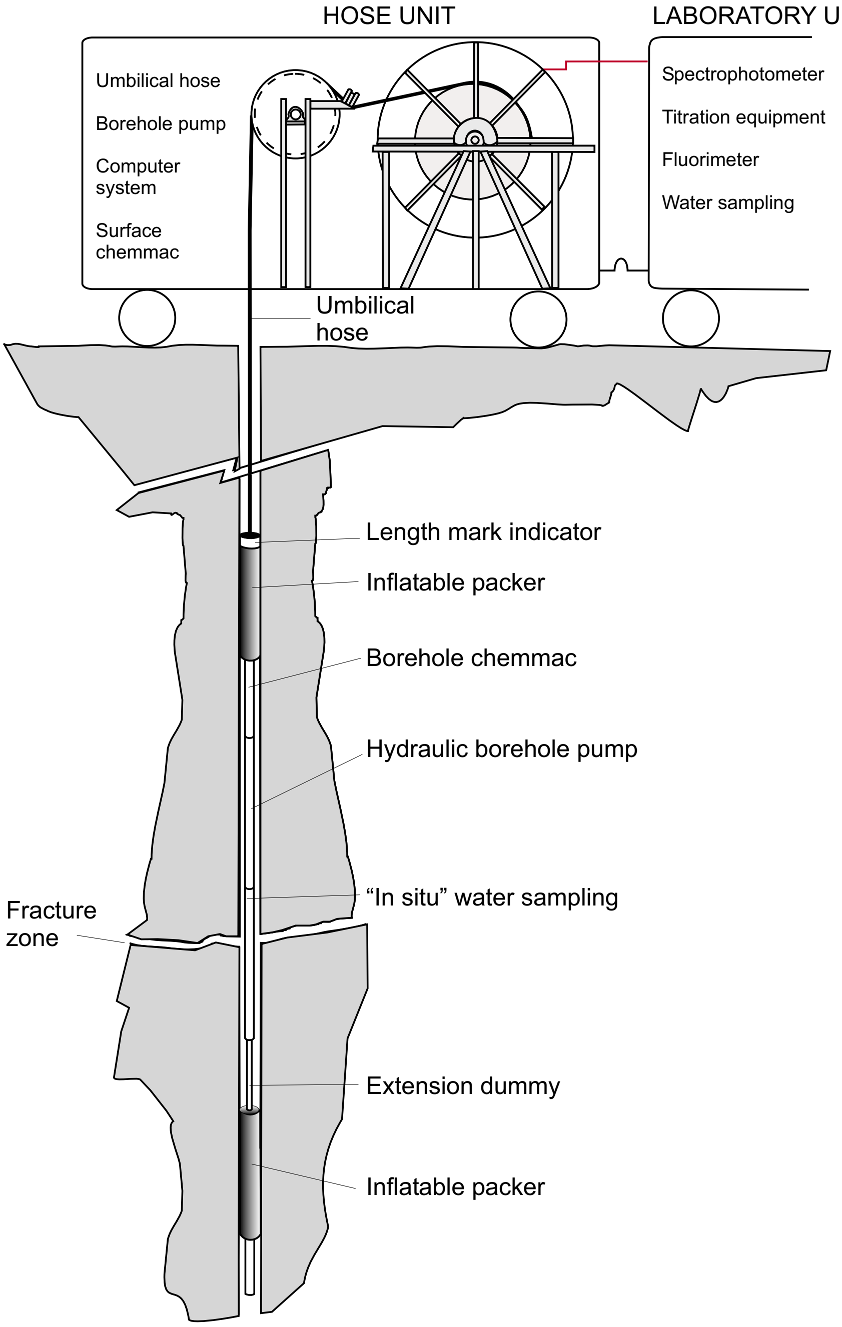

***Figure 3-2.** A schematic presentation of a mobile field laboratory; hose unit, laboratory unit and downhole equipment. The configuration of the downhole units in the borehole can be varied depending on desired section length. However, the in situ water sampler must always be positioned first in the sample water path.*

3.2 Equipment for enrichment of humic and fulvic acids

The enrichment of humic and fulvic acids is conducted in order to collect enough material to determine $\partial^{13}C$ and pmC on organic constituents in the groundwater. The equipment for enrichment includes a porous column and a textile filter with defined pore size and filled with an anion exchanger (DEAE-cellulose). The textile filter is placed inside the column in order to prevent the ion exchange resin from diffusing through the column. Technical details of the equipment and performance according to SKB MD 431.044 (SKB internal controlling document). Figure 3-3 shows the equipment setup.

Figure 3-3. *Water from the borehole passes through the ion exchanger in the column.*

3.3 Equipment for fractionation of humic and fulvic acids

The equipment consists of membrane filters with defined cut off (pore size), a peristaltic pump, flexible tubing and vessels. Generally, one water sample from each section is filtered through two filters with different pore sizes, 1,000 D and 5,000 D (D=Dalton, 1D=1g/mol). The equipment and performance is described in SKB MD 431.043 (SKB internal controlling document). Figure 3-4 presents the equipment setup.

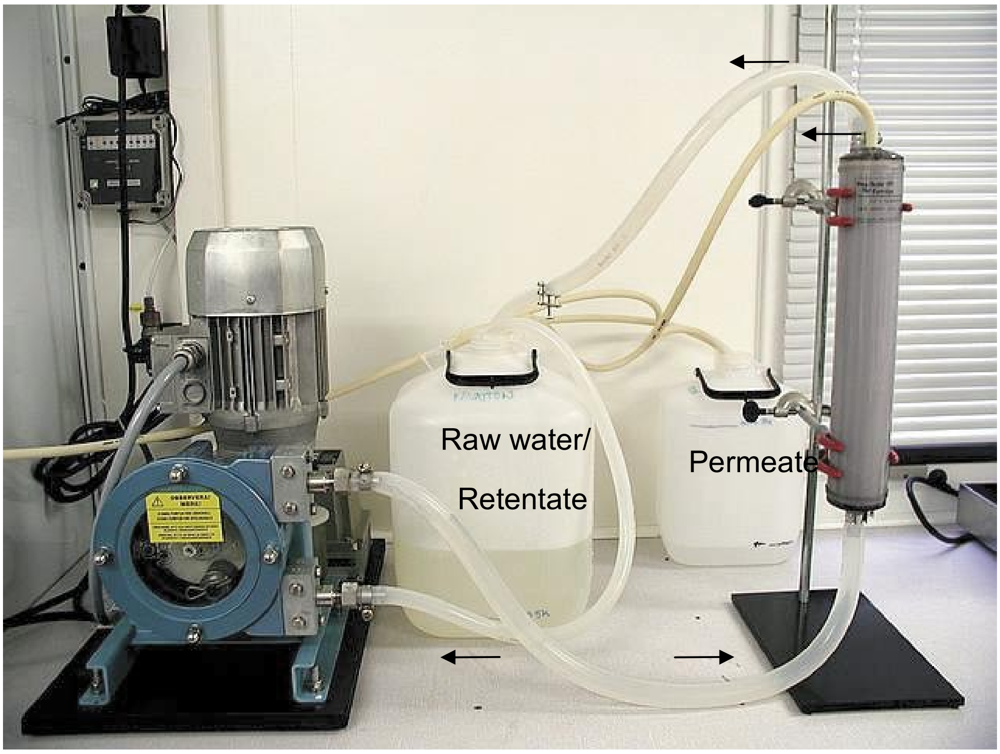

Figure 3-4. *Equipment used for fractionation of humic and fulvic acids.*

3.4 Colloid filtering equipment

The colloid filtering equipment/method is not yet approved. The equipment is used to determine the concentration of colloids in pressurised water samples. The equipment, Figure 3-5, is described in SKB MD 431.045 (SKB internal controlling document to be published)

The method has earlier been used under realistic conditions in borehole KFM01A to test and verify the method according to the activity plan AP PU 400-03-002 (SKB internal controlling document).

The sample for colloid filtration is an in situ groundwater sample which is collected in each borehole section with the pressurised ground water sampling system (PVP) in four sample containers (PVB). Two of them are generally used for colloid filtration. The groundwater is filtered through a series of connected filters in a closed system. The pressure is maintained under argon atmosphere at the same level as the pressure in the sampled borehole section. The intention is that colloids should be collected on the different filters (descending pore sizes) according to their size. Each filtration results in five filter samples (two 0.4 µm, one 0.2 µm and two 0.05 µm filter pore size) and two water samples (water in and water out). All samples are sent for ICP analysis (major components and common trace metals).

The major equipment features:

- Filtering is performed in a closed system at argon atmosphere thus avoiding the risk of iron precipitation due to contact between the groundwater sample and air.

- Filtering is performed at a pressure similar to that of the groundwater in the borehole section since the sample container maintains the pressure. The system is adjusted to create a pressure difference between the inlet of the filter package and the outlet side, the pressure difference drives the sample water through the filters.
- The design of the sample containers and the mounting with the outlet at the top prevents migration of the larger particles, which may clog the filters. Furthermore, clogging is prevented also by the first two filters with pore size 0.4 µm which are mounted parallel to each other.

Disadvantages/drawbacks, which may cause modifications of the equipment:

- The sample volume is limited to maximum of 2×190 mL.
- The PVB sample containers are made of stainless steal and contamination may occur. If the filtering method proves to be successful, an improvement would be to use Teflon coating on the inside of the cylindrical containers.

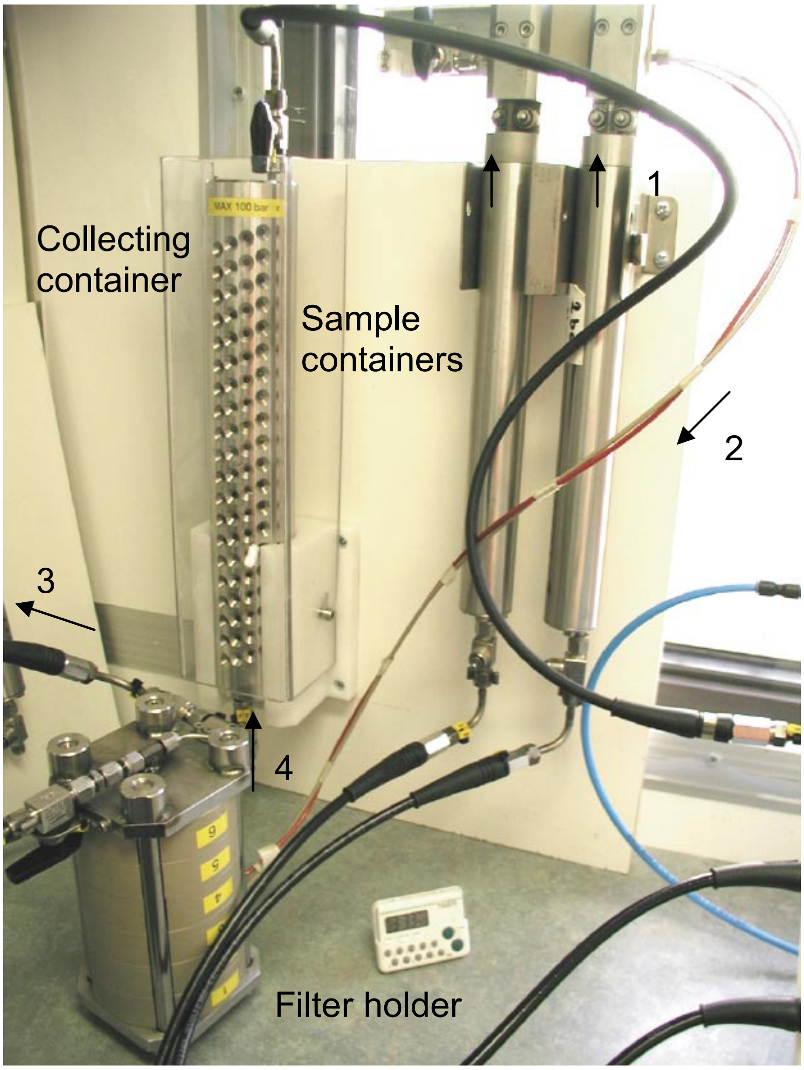

Figure 3-5. *The colloid filtering equipment including the sample containers, the filter holder package and the collecting container. The black arrows, 1-4, give the flow direction of the sample water through the system.*

3.5 Equipment for sampling of microbes

The sampling equipment for microbes is part of the downhole equipment and consists of one sample container (PVB) from the pressurised ground water sampling system (PVP). The system is designed to maintain pressure and temperature at the actual borehole depth of the investigated section, since changes in pressure and temperature may affect the results of the analysis. The method used for determination of microbes from the water sample is described in a primary report, Appendix 1.

3.6 Equipment for sampling of dissolved gases

One of the sample containers (PVB) from the pressurised ground water sampling system (PVP) is used for sampling of water for analysis of dissolved gases. The container is designed to maintain pressure and temperature at the actual depth of the investigated section.

4 Performance

Complete chemical characterisation in KSH01A was performed according to activity plan AP PS 400-02-33 following the method described in SKB MD 430.017 (SKB internal controlling document).

4.1 Choice of borehole sections

The investigation of the borehole starts with a choice of borehole sections. The choices of sections and the lengths of the sections are made using data from BIPS*-filming, differential flow logging and geophysical logging of temperature and electric conductivity. The final decision is supported by drilling water budget analysis, depth, appropriate mineralogy, hydraulic and hydro-chemical data.

Preliminary results from the differential flow logging indicate that there are no water-bearing zones between 300–550 m and 600–1,000 m. Flow rates above 10,000 mL/h are found in sections located at 160, 250, 259, 290 and 590 m and flow rates < 10,000 mL/h are found at 118, 270 and 558 m. Based on this, the sections at 160, 250, 290, and 590 m is chosen. One additional section is chosen from the following sections; 259, 270 and 558 m (AP PF 400-02-33, SKB internal controlling document). The investigated sections were 156.5–167.0 m, 245.0–261.6 m, 586.0–596.7 m and 548.0–565.4 m.

4.2 Overview of field work procedure

An overview of the Complete chemical characterisation in the borehole is given in this chapter.

The investigation was performed according to SKB MD 430.017-01 (SKB internal controlling document) compound by the following steps, each of them according to detailed description given in the SKB internal controlling document presented in parenthesis.

1. Establishment of mobile field laboratory at the borehole (SKB MD 434.007-01, SKB MD 434.005-01).
2. Cleaning of the umbilical hose.

The outside of the umbilical hose was cleaned with a cloth and 70% de-naturised ethanol, while the inside was cleaned with 15 ppm chlorine dioxide, prepared with de-ionised de-oxygenised water. The inside was thereafter rinsed with de-ionised de-oxygenised water in abundance (SKB MD 600.004).

3. Calibration of electrodes in borehole Chemmac (SKB MD 434.007-01ω).
4. Mounting of electrodes in borehole and surface Chemmac (SKB MD 434.006-01 and SKB MD 434.007-01).

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* BIPS-Borehole Image Processing System

5. Mounting of downhole equipment (SKB MD 434.006-01).
6. Lowering of downhole equipment, Appendix A3-1 to A3-4, and borehole Chemmac (SKB MD 434.006-01).
7. Length calibration of the umbilical hose (SKB MD 434.006-01).
8. Calibration of electrodes in surface Chemmac (SKB MD 434.007-01[ω]). The last calibration is used as an initial calibration for the next investigated section when possible.
9. Water pumping /SKB MD 452.001-01/, Chemmac measurement (SKB MD 434.007-01) and sampling of water (SKB MD 452.001-01).

Changes in water composition are monitored using registered conductivity values and/or analysed water samples class 2. When conductivity values have stabilised, samples for analyses of class 4 and 5 are taken each week. The continuous measurement proceeds until, if possible, the redox potential have stabilised, which normally takes two or three weeks. A class 5 sample icluding all options is taken at the end of the measuring period.

10. Analyses (SKB laboratory, external laboratories and field analyses).
11. Sampling for fractionation (SKB MD 431.043) and enrichment (SKB MD 431.044) of humic and fulvic acids.

The enrichment was performed during approximately two weeks while the fractionation was performed at the end of the measuring period.

12. Sampling of pressurised water in four sample container (PVB) in the PVP equipment (SKB MD 434.006-01) for colloid filtering (SKB MD 431.045, in progress), and analysis of dissolved gases and microbes.
13. Calibration of electrodes in borehole Chemmac.
14. Calibration of electrodes in surface Chemmac.
15. Calculation of calibration constants from Chemmac measurements.
16. Calculation of measurement data in Hilda.
17. Quality control of analyses and measurement data and storage in SICADA.

All the method descriptions and instructions above are SKB internal controlling documents

For sections 156.5–167.0 m and 245.0–261.6 m the data from the enrichment and fractionation of humic and fulvic acids, colloid filtration, gas and microbe analyses were given SKB no 54XX, see Table 4-1 and 4-2, while in section 4 they were given a common number, which is the number of the last water sample in the section.

4.3 Performance in section 156.5–167.0 m

The configuration of the downhole equipment is given in Appendix 2, A2-1.

The events during the measurement period for the borehole section 156.5–167.0 m is listed in Table 4-1.

[ω] 3.6 g/L Kinhydrone

Table 4-1. Events during the pumping/measurement period in section 156.5–167.0 m.

Date	Activity	SKB sample no: xxxx Improvement/deviation no: x
2003-03-25	Delivery of PVB.	Improvement/deviation no:1
2003-03-25	Security setup for the downhole equipment did not fit.	2
2003-03-26	Screw thread is cleaned on the chemistry probe.	3
2003-03-26–2003-04-23	No collection container for water from the field laboratory.	11
2003-03-27	Probably a broken electrode channel in the chemistry probe KE 021.	4
2003-03-27	Lack of material/materials in the field laboratory.	6
2003-03-27	**Lowering** of equipment.	
2003-03-28	Water sampling: SKB class 2.	5,256
2003-03-31	Water sampling: SKB class 4.	5,257
2003-03-31	No packaging for sending of water samples to external laboratories.	5
2003-03	Lack of information about water parameters for preparation of microbe media.	12
2003-04-02	**Lifting**, change of borehole pump and then **lowering** of equipment (due to loss of flow).	
2003-04-03	Water sampling: SKB class 2; pH, cond., alk., anions, uranine, Fe(II), Fe-tot and archive samples.	5,258
2003-04-03	Interruption of measurements due to broken spring in the borehole pump.	7
2003-04-07	Water sampling: SKB class 5.	5,259
2003-04-08–2003-04-23	No contact with the borehole Chemmac, electric power/communication problem.	8
2003-04-10	Humic and fulvic acids; enrichment start.	5,422 (5,263)
2003-04-10	Water sampling: SKB class 4.	5,260
2003-04-14	Water sampling: SKB class 5.	5,261
2003-04-16	Water sampling: SKB class 5.	5,262
2003-04-22	Water sampling: SKB class 5.	5,263
2003-04-22	Humic and fulvic acids: fractionation.	5,407–5,414 (5,263)
2003-04-22	Humic and fulvic acids; enrichment stop.	5,422 (5,263)
2003-04-23	**Lifting** of equipment.	
2003-04-23	Sampling of colloids, microbes and dissolved gases.	(5,263)
2003-04-23	Colloid filtration.	5,415–5,421 (5,263)
2003-04-23	Delay due to re-installation of electric power 2003-04-23.	10

4.4 Performance in section 245.0–261.6 m

The configuration of the downhole equipment is given in Appendix 2, A2-2.

The events during the measurement period for the borehole section 245.0–261.6 m is listed in Table 4-2.

Table 4-2. Events during the pumping/measurement period in section 245.0–261.6 m.

Date	Activity	SKB sample no: xxxx Improvement/deviation no: x
2003-04-24	**Lowering** of equipment.	
2003-04-24	Communication problem, possibly due to the inflatable packer.	9
2003-04-25	Water sampling: SKB class 2.	5,264
2003-04-26	Humic and fulvic acids; enrichment start	5,423 (5,269)
2003-04-28	Pressure of inflatable packer is low. About 3 bars, should be about 10 bars.	17
2003-04-29	Water sampling: SKB class 4.	5,265
2003-05-02	Water sampling: SKB class 5.	5,266
2003-05-05	Lack of information about water parameters for preparation of microbe media.	13
2003-05-08	Water sampling: SKB class 4.	5,267
2003-05-09	Delay in distribution of calculated data, since the measurement files could not be used in the calculation program HILDA.	14
2003-05-12	Water sampling: SKB class 5.	5,268
2003-05-13	No registration of data in the measurement application.	18
2003-05-14	HILDA is not adapted to the measurement application, which results in extra calculation steps when the conductivity values are calculated.	15
2003-05-14	No plots/figures in the measurement application.	19
2003-05-15	Water sampling: SKB class 4.	5,269
2003-05-19	Calibration of flow. Qmanual is not the same as Qmeasurement application.	16
2003-05-19	No flow. 2003-05-19 065601, Q=0. The PVB:s are filled up. Fractionation of humic and fulvic acids was cancelled. Density sample and archive samples are missing from the section.	20
2003-05-19	Humic and fulvic acids; enrichment stop.	5,423(5,269)
2003-05-19	**Lifting** of equipment.	
2003-05-19	Sample of colloids, microbes and dissolved gases.	5,269
2003-05-20	Colloid filtration.	5,424–5,430 (5,269)

4.5 Performance in section 586.0–596.7 m

The configuration of the downhole equipment is given in Appendix 2, A2-3.

The events during the measurement period for the borehole section 586.0–596.7 m is listed in Table 4-3. The measurements were interrupted due to high content of flushing water and the downhole equipment, Chemmac/umbilical hose, was serviced. After the service, the section at 548.0–565.4 m was characterised.

The water sampling/analysis of SKB class 2 in the section was reduced to pH, electric conductivity, flushing water content, hydrogen carbonate and chloride.

Table 4-3. Events during the pumping/measurement period in section 586.0–596.7 m.

Date	Activity	SKB sample no: xxxx Improvement/deviation no: x
2003-05-21	**Lowering** of equipment.	
2003-05-21	The airflow in the closed hood is low. Safety risk.	21
2003-05-22	No contact with the borehole chemistry probe.	22
2003-05-22	**Lifting** of equipment due to loss of contact with the probe.	
2003-05-23	**Lowering** of equipment.	
2003-05-26	Water sampling: SKB class 2.	5,270
2003-05-28	No flow when the surface Chemmac is installed and irregular flow when the surface Chemmac is uninstalled.	23
2003-05-28	Qmanual ≠ Qmeassurement application.	24
2003-06-06	Water sampling: uranine analysis at Äspö laboratory.	
2003-06-10	Water sampling: uranine analysis.*	
2003-06-10	The air condition in L2 is out of operation.	25
2003-06-11	Water sampling: uranine analysis in field.	
2003-06-13	Water sampling: uranine analysis.*	
2003-06-16	Water sampling: uranine analysis.*.	
2003-06-17	**Lifting**.	
2003-06-17	Borehole equipment is lifted due to repairs of the umbilical hose.	26

* Uranine analysis made at Geosigma AB.

4.6 Performance in section 548.0–565.4 m

The configuration of the downhole equipment is given in Appendix 2, A2-4.

The events during the measurement period of the borehole section 548.0–565.4 m is given in Table 4-4. The water sampling/analyses of SKB class 2 in the section was reduced to pH, electric conductivity, flush water content, hydrogen carbonate and chloride because of the relatively high flushing water content.

Table 4-4. Events during the pumping/measurement period in section 548.0–565.4 m.

Date	Activity	SKB sample no: xxxx Improvement/deviation no: x
2003-06-24	PVP probe does not work.	27
2003-06-24	**Lowering** of equipment.	
2003-06-26	Water sampling: SKB class 2.*	5,271
2003-07-01	Water sampling: uranine analysis.*	
2003-07-03	Water sampling: uranine field analysis.	
2003-07-05	Loss of flow is observed.	
2003-07-05	No flow from the section due to broken spring in borehole pump.	28
2003-07-08	No contact with the PVP. The containers are filled up with depression.	29
2003-07-08	**Lifting** of equipment followed by change of pump before **lowering** again.	
2003-07-10	Lost contact with umbilical hose.	
2003-07-10	No contact with the borehole probe, short-circuit.	30
2003-07-10	**Lifting**, repairing.	
2003-07-11	**Lowering**.	
2003-07-15	Water sampling: SKB class 2, uranine field analysis.	5,272
2003-07-17	Water sampling: SKB class 2, uranine field analysis.	5,273
2003-07-21	Water sampling: SKB class 2, uranine field analysis.	5,274
2003-07-21	Qmanual ≠ Qmeasurement application..	31
2003-07-24	Loss of flow.	
2003-07-24	No flow from the section due to broken spring in borehole pump.	32
2003-07-28	**Lifting** of equipment for change of pump followed by **lowering**.	
2003-07-30	Water sampling: uranine field analysis.	
2003-07-31	Water sampling: SKB class 2, uranine field analysis.	5,275
2003-08-04	Water sampling: SKB class 2, uranine field analysis.	5,276
2003-08-07	Water sampling: SKB class 2, uranine field analysis.	5,277
2003-08-11	Loss of flow is observed.	
2003-08-11	No flow from the section, Q=0, 2003-08-09. The drift pump for the borehole pump does not work, the magnet valve is changed and the clock is modified.	33
2003-08-13	A leak from the drift pump, from a plunger.	34
2003-08-14	Water sampling: SKB class 2.	5,278
2003-08-18	Water sampling: SKB class 2.	5,279
2003-08-21	Water sampling: SKB class 5.	5,280
2003-08-25	Water sampling: SKB class 1/uranine.	5,281
2003-08-26	The measurement application: • Writes wrong borehole length, for instance, on the administration page. • The message: ”Message from MATDATOR1 to ARBETSGRUPP… MATDATOR is on battery…shutdown in 10 mins”	35
2003-08-26	Humic and fulvic acids; enrichment start.	5,288
2003-08-28	Water sampling: SKB class 1/uranine.	5,282
2003-08-29	Water sampling: uranine field analysis.	
2003-09-01	Water sampling: SKB class 1/uranine.	5,283
2003-09-05	Water sampling: SKB class 1/uranine.	5,284
2003-09-08	Water sampling: SKB class 1/uranine.	5,285
2003-09-09	Q=0, the borehole pump does not work. No flow from the section due to broken spring in the borehole pump. The borehole pump is changed.	37
2003-09-09	Humic and fulvic acids; enrichment stop.	5,288
2003-09-10	**Lifting** of equipment to change borehole pump followed by **lowering.**	

Date	Activity	SKB sample no: xxxx Improvement/deviation no: x
2003-09-11	Water sampling: SKB class 1/uranine.	5,286
2003-09-12	Water sampling: SKB class 1/uranine.	5,287
2003-09-15	Water sampling: SKB class 5.	5,288
2003-09-15	Humic and fulvic acids; fractionation (5.000 D).	5,288
2003-09-15	The fractionation of humic and fulvic acids with 1.000 D filter will be done later due to defect filter. Water from the section is deep frozen.	36
2003-09-16	Lifting.	
2003-09-16	Sample of colloids, microbes and dissolved gases.	5,288
2003-09-17	Colloid filtration.	5,288
2003-10-27	Humic and fulvic acids; fractionation (1.000 D).	5,288

* Uranine analysis made at Geosigma AB.

4.7 Water sample treatment and analyses

An overview of sample treatment and analysis routines of major components, minor anions, trace metals and isotopes is given in Appendix 3. The routines are applicable independently of sampling method or sampling object.

4.8 Enrichment of humic and fulvic acids

The enrichment of humic and fulvic acids was conducted in order to collect enough material to determine $\partial^{13}C$ and pmC in organic constituents in the groundwater. The enrichment method entails collection of organic acids on an ion exchanger, eluation of the resin and evaporation of the resulting solution. The method is described in SKB MD 431.044 (SKB internal controlling document). The dry residue is used for the isotope determination; a minimum amount of 10 mg organic carbon is needed. In addition to organic material the residue also contains sodium hydroxide from the eluation. The sample is acidified at the relevant laboratory prior to analysis in order to exclude the carbon dioxide.

4.9 Fractionation of humic and fulvic acids

Humic and fulvic acids were fractionated with respect to molecular weight using an ultra filtration technique. The method is described in SKB MD 431.043 (SKB internal controlling document).

Sampled water from two sections at 156.5–167.0 and 548.0–565.4 m were filtered through membrane filters with a cut off of 1,000 D and 5,000 D. The initial water volumes prior to filtration were approximately 5 litres. The final retentate and permeate volumes following filtration were approximately 1 and 4 litres respectively, which gave an enrichment factor of five in the retentate.

Water samples were collected from the retentate and the permeate as well as from the original groundwater in the borehole section. Each sample was analysed for dissolved organic carbon (DOC), major components and common trace metals. The analyses of metal ions are conducted in order to detect any precipitation of metals that could possibly lead to co-precipitation of the humic and fulvic acids. Furthermore, the analyses of metal ions should indicate if metals such as Al, Si, Mn and Fe exist as colloidal species.

Since the filter for 1,000 D broke during fractionation in section 4 (15th of September), the water sample was deep frozen and fractionated with the 1,000 D filter the 27th of October. After melting the sample, it was filtered through a 0.45 µm Pall filter before fractionation, due to visible precipitation. A water sample was sent for DOC analysis at the sampling occasion (15th of September) as well as before and after fractionation (27th of October) so that any changes in the DOC concentration could be registered.

4.10 Colloid filtration

Two of the four sample containers of the pressurised ground water sampling system (PVP) were used for colloid filtration (PVB cleaned and controlled before sampling). Before the filtration the colloid system is cleaned. New filters and deionised water was used. A leak test at 10 bar was also done before each sampling occasion in order to eliminate the risk of leakage during filtration. Thereafter, if no leakage was visible, the system was dried and put together.

The theoretical amount of water left in the sample container (PVB) is 12 ml. The colloid filtration filters from each sample, two 0.4 µm, one 0.2 µm and two 0.05 µm, water from the collection container and any remaining water from the downhole equipment (PVB) were sent for analysis, primarily aluminium, iron, manganese and silica (analysis of major components and common trace metals). The PVB containers from section 245.0–254.6 m were not completely filled.

Table 5-4. Colloid filtration performance.

Section/ sampling date	Entering pressure (bar)	Max. diff. pressure over filter package (bar)	Temp. (°C)	Filtering time (min)	Filtered volume (ml)	Comments
156.5–167.0 m/ 20030423	18	3.9	7	41	283.5	Broken filters: 0.2 µm and the first 0.05 µm.
245.0–261.6/ 20030520	26.5	3.2	(11) Laboratory temperature during filtration.	38	255.0	Broken filters: 0.2 µm and the first 0.05 µm. The water in the sampling container is colder than 11°C.
548.0–565.4/ 20030916	58	15.7	(14) Laboratory temperature during filtration.	170	306.0	Broken filter: the last 0.05 µm. The water in the sampling container is colder than 14°C.

4.11 Microbes

One of the four sample containers of the pressurised ground water sampling system (PVP) was sent for microbial analysis. The PVB container was lifted from the borehole and put on ice to maintain the temperature and sent to the laboratory as soon as possible for analysis. At the laboratory, the sample was collected in sterile tubes under nitrogen gas.

One sample container from the sections 156.5–167.0 m, 245.0–261.6 m and 548.0–565.4 m was analysed for total cell number and most probably number (MPN). For sample preparation and analysis methods see Appendix 1.

4.12 Dissolved gases

The container is designed to maintain the pressure and temperature from the investigated borehole section. At the laboratory, the container is purged with nitrogen gas in vacuum and pumped into a sample cylinder. The sample is then analysed for argon (Ar), helium (He), nitrogen (N_2), carbon dioxide (CO_2), methane (CH_4), oxygen (O_2), hydrogen (H_2), carbon monoxide (CO), ethane (C_2H_6), ethene (C_2H_4), acetylene (C_2H_2), propane (C_3H_8) and propene (C_3H_6) .

One of the PVB containers from the downhole equipment in the sections 156.5–167.0 m, 245.0–261.6 m and 548.0–565.4 m was sent for analysis of content and composition of dissolved gases.

4.13 Data handling

4.13.1 Measurement data

The measurement data (from the on-line Chemmac measurements) was calculated and evaluated in Hilda (specially developed calculation software). The evaluated data is reported in SICADA. An overview of the routine for treatment of measurement data (pH, Eh and electric conductivity) is given as follows;

1. Calibration files (*.CRB) and calibration comments (*.CI) for the electrodes in borehole and surface Chemmac are imported to Hilda (* is exchanged for borehole ID _ secup).
2. The calibration constants calculated from the calibration measurements are evaluated (SKB MD document is in preparation). The calibration comments are used as guidance for selecting appropriate calibration constants.
3. The selected calibration constants are used for re- calculation of the recorded measurement data (*.MRB files from Chemmac measurements). The calculated data is plotted in graphs. Files containing information (*.MI) about the measurements are used as support for deleting apparently deviating values. Any changes of the Chemmac measurement data are noted in *comments.mio.
4. Three files with selected calibration constants, evaluated data and comments are generated and reported to SICADA; (*constants.mio, *measurements.mio and *comments.mio).

4.13.2 Water analysis data

The following routines for quality control and data management are generally applied for hydrogeochemical analysis data, independently of sampling method or sampling object.

Several components are determined by more than one method and/or laboratory. Moreover, control analyses by an independent laboratory are performed as a standard procedure on each fifth or tenth collected sample.

All analytical results is stored in the SICADA database. The hierarchy path "Hydrochemistry/Hydrochemical investigation/Analyses/Water in the database" contains two types of tables, raw data tables and primary data tables (final data tables).

Data on basic water analyses are inserted into the raw data tables for further evaluation. This evaluation results in a final reduced data set for each sample. These data sets are compiled in a primary data table named "water_composition". The evaluation is based on:

- Comparison of results from different laboratories and/or methods. The analyses are repeated if a large disparity is noted (generally more than 10%).
- Calculation of charge balance errors. Relative errors within ± 5% are considered acceptable (in surface waters ± 10%).

  $$\text{Relative error } [\%] = 100 \cdot \frac{\sum cations(equivalents) - \sum anions(equivalents)}{\sum cations(equivalents) + \sum anions(equivalents)}$$

- General expert judgement of plausibility of results, based on earlier results and experiences.

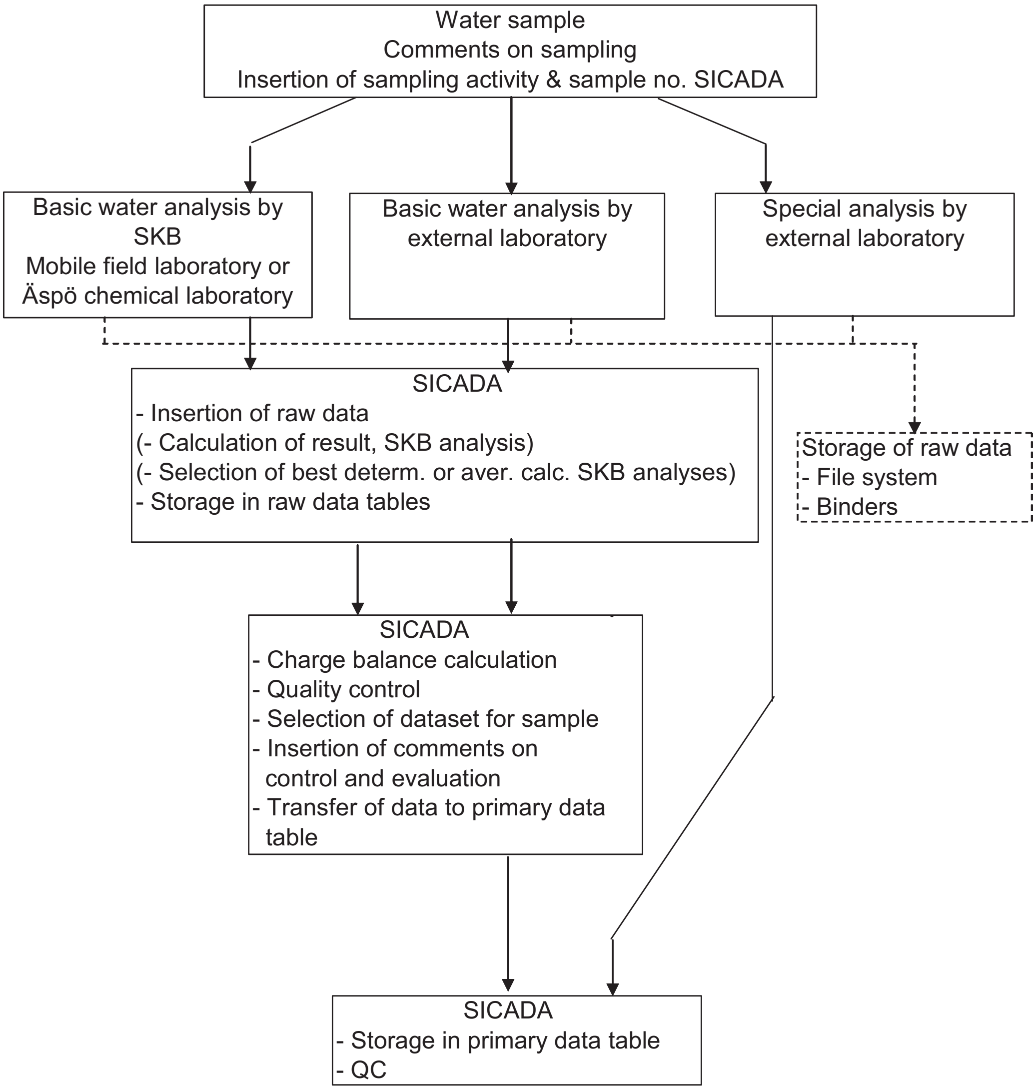


Figure 4-1. *Overview of data management system for hydrogeochemical data.*

All results from special analyses of trace metals and isotopes are inserted directly into the primary data tables. In cases where the analyses are repeated or performed by more than one laboratory, a “best choice” notation indicates the results that are considered most reliable.

An overview of the data management system is given in Figure 4-1.

4.13.3 Data from special sampling activities

The analysis data from special sampling activities are stored in the file archives in the SICADA database. Data are subject to quality control and stored in tables in the SICADA database.

Enrichment of humic and fulvic acids

Carbon-13 and pmC results are directly inserted into the primary data tables in SICADA.

Fractionation of humic and fulvic acids and inorganic colloids

The concentrations of humic and fulvic acids in the permeate and retentate after fractionation with 1,000 D and 5,000 D filters, are calculated from the DOC analyses. The results are given as:

- Fraction < 1,000 D
- Fraction < 5,000 D but > 1,000 D
- Fraction > 5,000 D
- Adsorption

The same procedure is followed for the elements (inorganic colloids) analysed by ICP-AES.

A detailed description of performed calculations and equations used is given in the method description SKB MD 431.043. Calculated and evaluated results are stored in SICADA.

Colloids

The concentration is calculated with the assumption that the water volume coming out in the collecting container is equal to the volume going into the system. This is not quite true as up to ten millilitres will be left in cavities in the filter holder package, in the tubing and in valves. A small volume of about 0.01 to 0.06 mL is left in each filter after the filtration and its content of the different elements is included in the analysis. Calculated analysis results from colloid filtration (metals) are stored in SICADA. The measurement uncertainty of each colloid concentration is calculated according to equation (2).

$$U = \sqrt{\left(\frac{1}{V^2} \cdot (\Delta m)^2 + \frac{m^2}{V^4}(\Delta V)^2\right)} \qquad (2)$$

where
U = measurement uncertainty (µg/L)
V = water volume through the system (L)
ΔV = estimated volume error, 0.010 L
m = amount on filter (µg)
Δm = measurement uncertainty of the filter analysis, 20% (µg)

The calculated results from the colloid filtration, filters, are stored in SICADA. The water samples (in and outgoing water) are directly inserted into the primary data tables in SICADA.

Microbes

The results from the microbe analyses are stored in SICADA.

Dissolved gases

Results from gas analyses are directly inserted into the primary data tables in SICADA.

5 Nonconformities

The complete chemical characterisation of the four sections in KSH01A has been conducted according to the SKB internal controlling documents AP PS 400-02-33 and SKB MD 434.004, 434.005, 434.006, 434.007 and SKB MD 433.018. Some equipment malfunctions have occurred during the pumping/measurement periods (Tables 4-1 to 4-4) such as communication problems with the electrodes in borehole Chemmac and borehole pump failure.

The targeted upper limit for flushing water content, 1%, was exceeded in all sections; 156.5–167.0 m (3%), 245.0–261.1 m (8%), 548.0–565.4 m (11%) and 586.0–596.7 m (36%). Extended water sampling/analyses of uranine (flushing water) was made in the last sections. However, during prevailing circumstances it was concluded that it was not possible to reach a flushing water content below 1% in any of the sections. The fractionation in section 245.0–261.6 m was cancelled due to loss of water flow. The flow rate in section 245.0–261.6 m and 548.0–565.4 m measured with the measurement application did not agree with the manual measured flow, Figure A5-6 and A6-7. In section 586.0–596.7 m the investigation (including enrichment fractionation, colloid filtration, microbes and dissolved gases) was interrupted due to the high flushing water content and repairs of the downhole equipment, Chemmac/umbilical hose.

6 Results

6.1 Chemmac measurements

A representative measurement value for each electrode is selected at a logging occasion in a stable part of the measurement period in the end of the measurement. The standard deviation for each pH and Eh electrode is calculated from calibration constants obtained before and after each measurement. The "final" pH and Eh value, representative for the section, is given as a mean value for all pH and Eh electrodes respectively with calculated standard deviation (σ), Table 6-1.

The surface Chemmac measurements were conducted successfully, in sections 156.5–167.0, 245.0–261.1 and 548.0–565.4 m, the whole measurement sequences of electric conductivity, pH, dissolved oxygen, Eh, temperature and water flow are plotted versus time in Appendix 4 to Appendix 6. The flow rate in section 245.0–261.6 m and 548.0–565.4 m measured with the measurement application did not agree with the manual measured flow, Figure A5-6 and A6-7. The borehole Chemmac measurements failured in the four sections due to communication problems with the electrodes and borehole pump failure.

The concentration of dissolved oxygen decreased, in all sections, to below detection limit after a few days of measurement. However, the concentration is increasing temporarily during lifting of the equipment.

For section 156.5–167.0 m there is a discontinuity in the graphs due to lifting of the equipment when the borehole pump was replaced (2003-04-02), Appendix 4.

Also, for section 548.0–565.4 m there are some discontinuities in the graphs due to lifting of the equipment. The values are stabilised at the end of the measuring period, end of August to beginning of September, Appendix 6.

Table 6-1. Evaluated results from the Chemmac measurements in KSH01A.

Borehole section (m)	Electric conductivity* (mS/m)	pH	Eh (mV)	Dissolved oxygen** (mg/L)
156.5–167.0	1,558 ± 100	8.17 ± 0.16	–257 ± 20	0 ± 0.01
245.0–261.6	1,787 ± 100	8.08 ± 0.17	–160 ± 36	0 ± 0.01
548.0–565.4	2,397 ± 100	8.15 ± 0.16	–173 ± 20	0 ± 0.01

* The electric conductivity is measured between 0–10,000 mS/m with a resolution of 1% of the measurement interval.

** Measuring interval 0–15 mg/L, resolution 0.01 mg/L.

6.2 Water analyses

6.2.1 Basic water analyses

The basic water analyses includes the major components Na, K, Ca, Mg, S, SO_4^{2-}, Cl^-, Si and HCO_3^- as well as the minor constituents Fe, Li, Mn, DOC, Br, F, HS^- and NH_4^+. Further, batch measurements of pH and electric conductivity are included. The content of flushing water in each sample is also an important parameter. The basic water analysis data are compiled in Appendix 7, Table A7-1. Existing batch measurement values of pH and electric conductivity (last collected sample in each section) are compared to the corresponding online Chemmac measurement values in the diagrams in Appendix 4 to Appendix 6.

The charge balance errors give an indication of the quality and uncertainty of the analyses of the major components. The relative charge balance errors were calculated the selected sets of data; see Appendix 7, Table A7-1. The errors do not exceed ± 5% in any case when incomplete data sets are excluded. A comparison between results from different laboratories and methods indicates that the agreement is acceptable in most cases. The difference in concentration between each controlled component is generally less than 10%.

The flushing water contents in the samples collected in the four borehole section are presented in Figure 6-1, the field analyses are excluded. The analyses data with outlines, in the graph below, are values not stored in SICADA. The flushing water content should not exceed 1% in a sample considered representative for the groundwater of the fracture zone. This condition was not met in any of the sections.

The pH and concentration of chloride and hydrogen carbonate respectively are presented in Figure 6-2 to Figure 6-4. The pH is similar in all investigated sections.

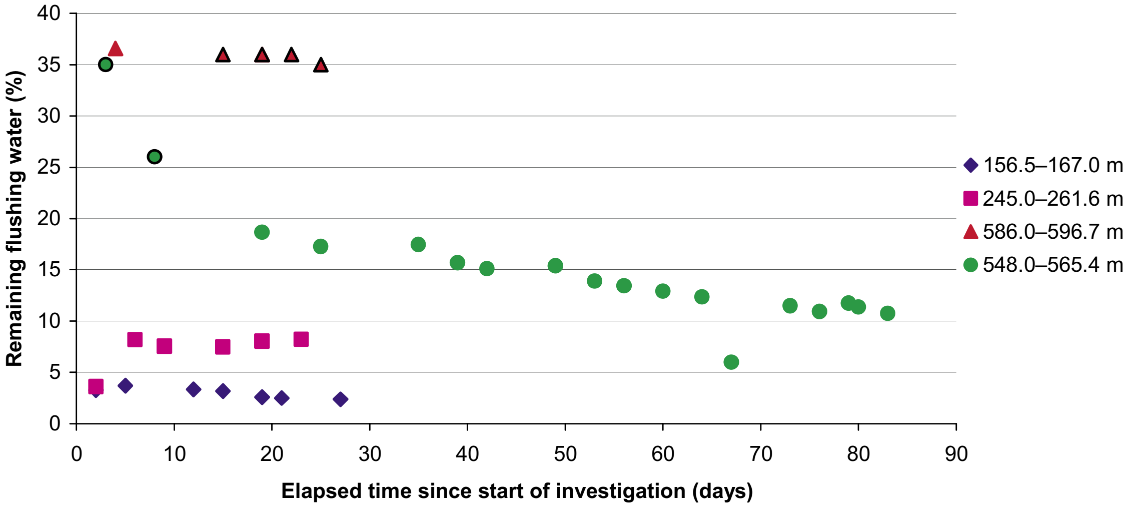


Figure 6-1. Flushing water content in the sections during the investigation period. The data points with outlines are not stored in SICADA.

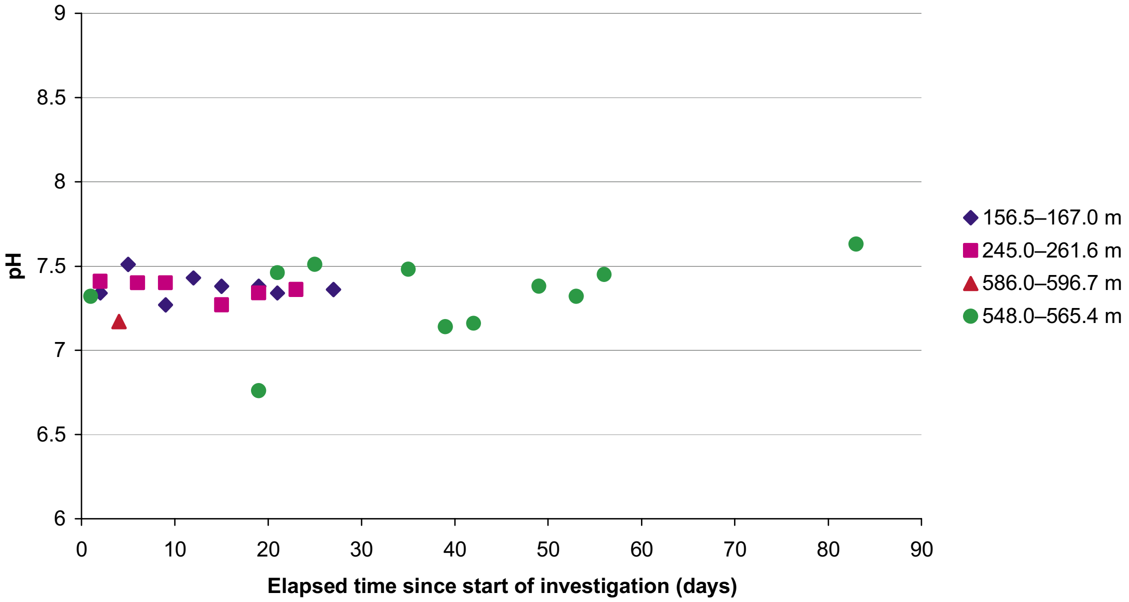


Figure 6-2. pH in the sections during the investigation period.

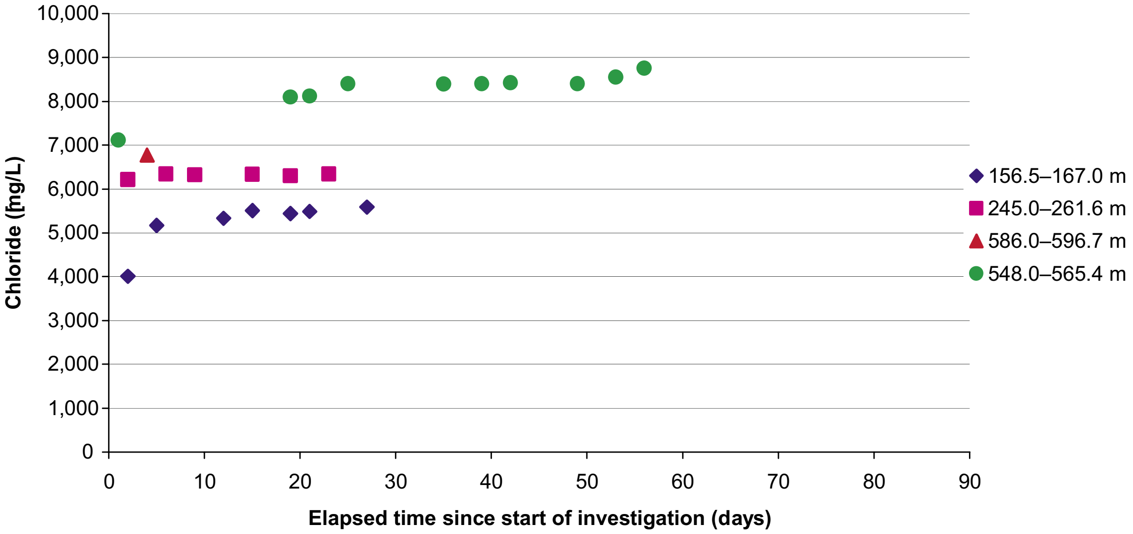


Figure 6-3. Chloride in the sections during the investigation period.

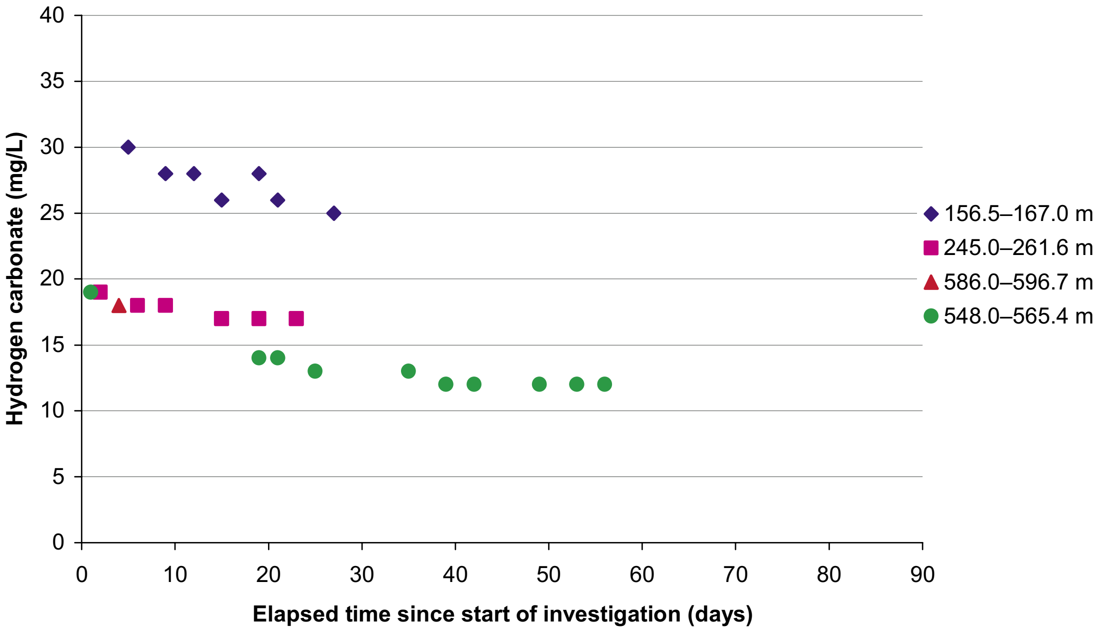


Figure 6-4. *Hydrogen carbonate in the sections during the investigation period.*

The chloride concentrations are plotted versus the corresponding electric conductivity values in Figure 6-5. The data from the borehole sections, 156.5–167.0 m, 245.0–261.6 m and 548.0–565.4 m, agree well with the line obtained by earlier data from the Äspö Hard Rock Laboratory. The plot gives a rough control that the values are reasonable.

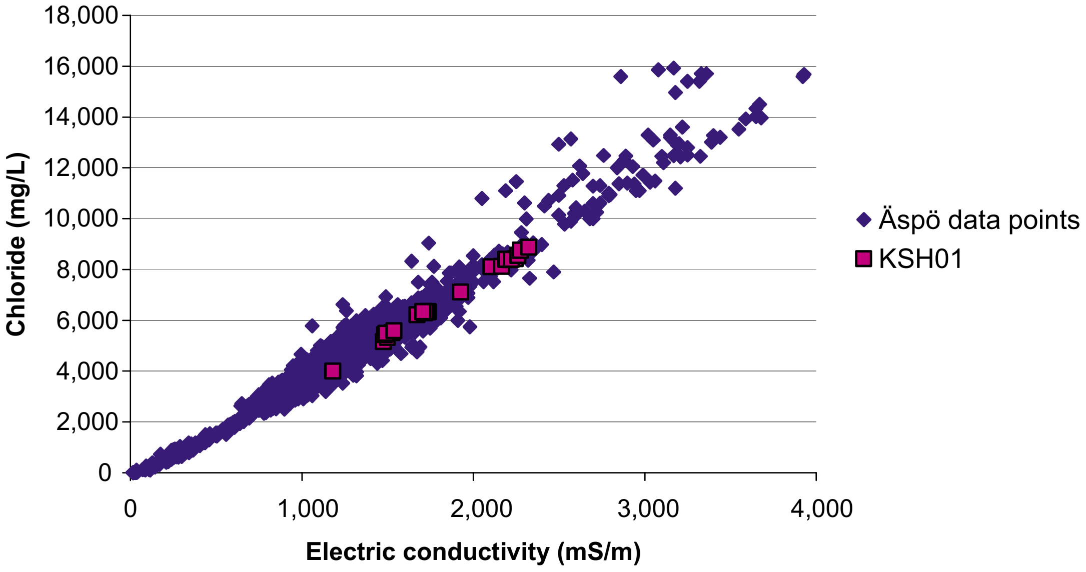


Figure 6-5. *Chloride versus electric conductivity. Data from earlier investigations at the Äspö hard rock laboratory are used to show the linear trend. The data from KSH01A do not deviate from a regression line.*

6.2.2 Stable and radioactive isotopes

The isotope determinations include the stable isotopes δD, $\delta^{18}O$, $^{10}B/^{11}B$, $\delta^{34}S$, $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ as well as the radioactive isotopes Tr (TU), ^{14}C (pmC), ^{238}U, ^{235}U, ^{234}U, ^{232}Th, ^{230}Th, ^{226}Ra and ^{222}Rn. The isotope data are compiled in Appendix 7, Table A7-2 and Table A7-4.

The tritium and $\delta^{18}O$ results are presented in Figure 6-6 to Figure 6-7, respectively. The tritium content was below the detection limit (0.8 Tritium Units, 0.4±0.4 Tritium Units) in most samples collected in section 156.5–167.0 m and 245.0–261.6 m. From sections 586.0–596.7 m and 548.0–565.4 m there are only one and two results available respectively. The $\delta^{18}O$ ratios remained stable during the sampling periods.

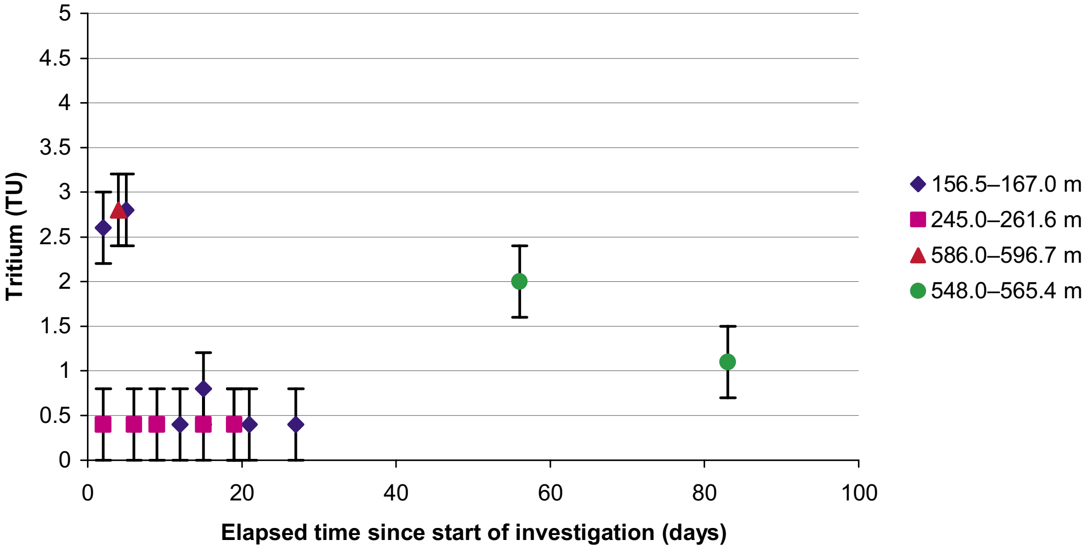


Figure 6-6. Tritium in the sections during the investigation period.

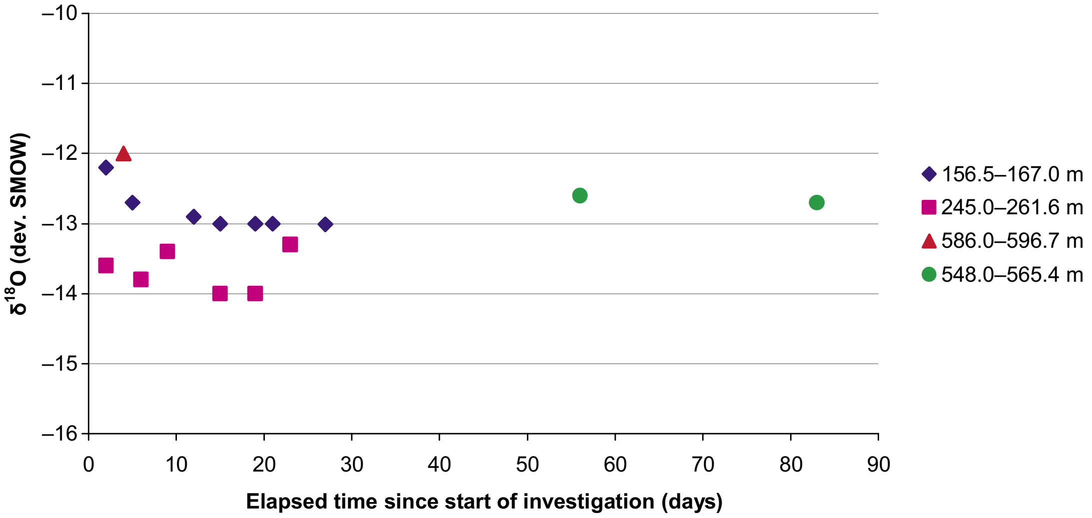


Figure 6-7. $\delta^{18}O$ in the sections during the investigation period.

6.3 Enrichment of humic and fulvic acids

The carbon isotopes ($\delta^{13}C$ and pmC) were determined in organic constituents, Table 6-2. Enrichment of organic carbon was necessary in order to get enough organic material. The enrichment was not performed in section 586.0–596.7 m due to high content of flushing water.

Table 6-2. Organic $\delta^{13}C$ and pmC.

Borehole section (m)	$\delta^{13}C$ (dev PDB)	pmC
156.5–167.0	x	x
245.0–261.6	–27.0	85.2
548.0–565.4	x	x

x = not enough carbon to perform the analysis.

6.4 Fractionation

6.4.1 Humic and fulvic acids

The results from fractionation of organic acids in the sections at 156.5–167.0 and 548.0–565.4 m are summarised in Table 6-3. As shown, the water in the sections contains organic acids with a molecular weight less than 1,000 D, except for a very small fraction larger than 5,000 D. This means that the organic constituents are present as low molecular weight fulvic acids and possibly other low molecular weight organic acids (e.g. citric acid, oxalic acid etc).

The fractionation in section 245.0–261.6 m was cancelled since there was no water flow from the section at the time for the fractionation. In section 586.0–596.7 m the content of flushing water was too high and the downhole equipment, borehole Chemmac/umbilical hose, had to be serviced.

Table 6-3. Summary of fractionation results.

Fraction	Section 156.5–167.0 m DOC concentration (mg/L)	Section 548.0–565.4 m DOC concentration (mg/L)
< 1,000 D	1.0 ± 0.1	1.0 ± 0.1
> 1,000 D but < 5,000 D	–	–
> 5,000 D	0.06 ± 0.04 (almost within the error)	0.04 ± 0.03 (almost within the error)

– = Not found

6.5 Inorganic colloids

The presence of inorganic colloids is investigated by two different methods. One method is colloid filtration (the results are not yet stored in SICADA) through a series of connected filters of different pore sizes. This method is new and not yet approved. A second method is fractionation/ultra filtration using cylindrical membrane filters with a cut off of 1,000 D and 5,000 D respectively. The results of the two methods are difficult to compare quantitatively but a qualitative agreement is identified.

6.5.1 Inorganic colloids-fractionation

Besides the DOC analyses, the samples from fractionation experiments were also analysed by ICP-AES. The determined elements were; Ca, Fe, K, Mg, Na, S, Si, Al, Ba, Cd, Co, Cr, Cu, Hg, Li, Mn, Mo, Ni, P, Pb, Sr, V and Zn. Only iron, silicon, aluminium and manganese were considered important as colloid species.

The results presented in Table 6-4 and Table 6-5 were calculated using mass balance equations (SKB MD 431.043, SKB internal controlling document). As shown, Fe, Si and Mn exist as species (associated or non-associated with humic and fulvic acids) with a molecular weight less than 1,000 D. Such species are too small to be referred to as colloids. The concentrations of aluminium in the water were too low to draw any conclusions regarding fractions of aluminium. Iron (and silicon) was partly precipitated during the fractionation, since oxygen is present in the filtering system (pump, filter, hose etc). Although unlikely, the presence of iron and silicon containing species of a larger fraction cannot be completely excluded.

Table 6-4. Inorganic fractions (1,000 D and 5,000 D filters) in section 156.5–167.0 m.

Fraction	Fe (mg/L)	Si (mg/L)	Mn (mg/L)
< 1,000 D	0.54 ± 0.05	3.5 ± 0.5	0.51 ± 0.05
< 5,000 D	0.77 ± 0.08	3.5 ± 0.5	0.52 ± 0.05
> 1,000 D but < 5,000 D	–	–	–
> 5,000 D	–	–	–
Adsorption 1,000 D	0.59 ± 0.13	–	–
Adsorption 5,000 D	0.36 ± 0.14	–	–

– = Not found.

Table 6-5. Inorganic fractions (1,000 D and 5,000 D filters) in section 548.0–565.4 m.

Fraction	Fe (mg/L)	Si (mg/L)	Mn (mg/L)
< 1,000 D	0.05 ± 0.01	2.9 ± 0.4	0.40 ± 0.04
< 5,000 D	0.35 ± 0.04	4.1 ± 0.6	0.41 ± 0.04
> 1,000 D but < 5,000 D	–	–	–
> 5,000 D	–	–	–
Adsorption 1,000 D	0.38 ± 0.05	1.5 ± 0.8	–
Adsorption 5,000 D	0.10 ± 0.06	–	–

– = Not found.

The filters were carefully washed before use and samples of de-ionised water (after passing through the washed filters) were analysed as sample blanks. The concentrations in the sample blanks were insignificant. The results from both sections show that Calcite was not precipitated to any significant extent during the filtrations.

6.5.2 Inorganic colloids-colloid filtration

The main results from the colloid filtration method conducted in the sections 156.5–167.0 m, 245.0–261.6 m and 548.0–565.4 m are presented in Figure 6-8 to 6-11, Figure 6-12 to 6-15 and Figure 6-16 to 6-19 respectively. Zero values in the graphs are values below the detection limit. Colloid filtration was not performed in section 586.0–596.7 m, the measurements were interrupted because of high flushing water content in the section.

The results are presented as amount (µg) of aluminium, iron, silicon and manganese going into the filter package, in each filter and in the collecting container. The amount is calculated with the assumption that the water volume coming out in the collecting container is equal to the volume going into the system. This is not quite true as up to ten millilitres will be left in cavities in the filter holder package, in the tubing and in valves. A small volume of about 0.01 to 0.06 mL is left in each filter after the filtration and its content of the different elements is included in the analysis.

Comments and conclusions regarding the results presented in Figure 6-8 to 6-19 follow below:

- The input amount of aluminium and iron is larger than the sum of the amounts recovered in the filters and in the output.
- The output concentrations of aluminium, iron, silica and manganese are close to the concentrations in the up pumped borehole water, except for iron in section 245.0–261.6 m.
- The input sample is collected after the filtration, from the small residual volume in the PVB-container. A possible explanation to the generally high input concentrations, when comparing with the concentration in the up pumped water, is that the sample water when poured from the PVB-container is in contact with the surface on the outlet. The source of contamination is probably the borehole section.
- A better control of the pressure differences between different positions in the filtering line or a more gentle pressure regulation and slower filtration might possibly prevent broken filters and improve the filtering performance. However, it can be noted that the amount of the different elements are not significantly different on broken filters compared to intact filters. Results obtained from broken filters are given within brackets in the diagrams, Figures 6-8 to 6-19.
- The concentrations of aluminium, iron, silica and manganese in filter sample blanks (just filter, no preparation) are insignificant.
- The results from the three sections show that Calcite was not precipitated to any significant extent during the colloid filtrations.

Result of colloid filtering using water sample from section 156.5-167.0 metres

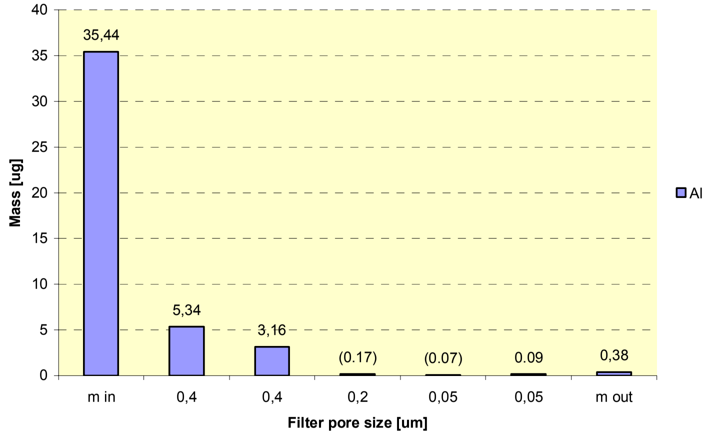


Figure 6-8. *Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).*

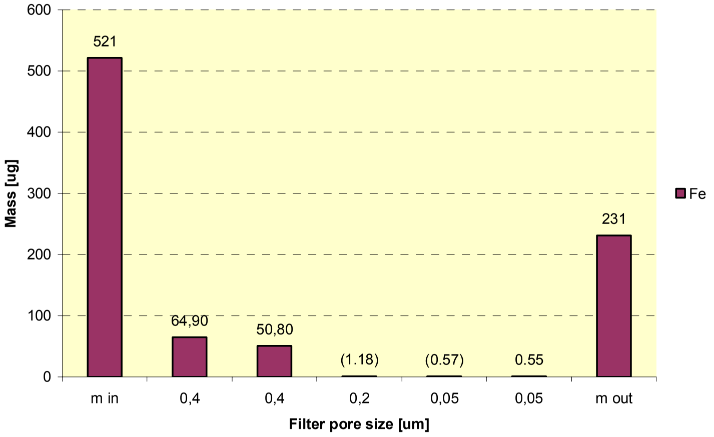


Figure 6-9. *Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).*

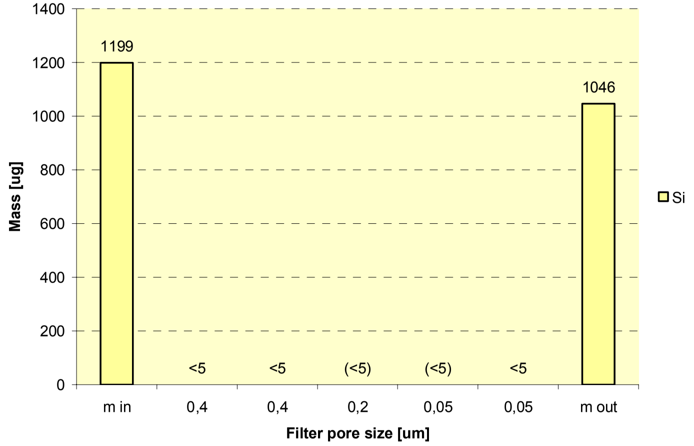


Figure 6-10. *Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

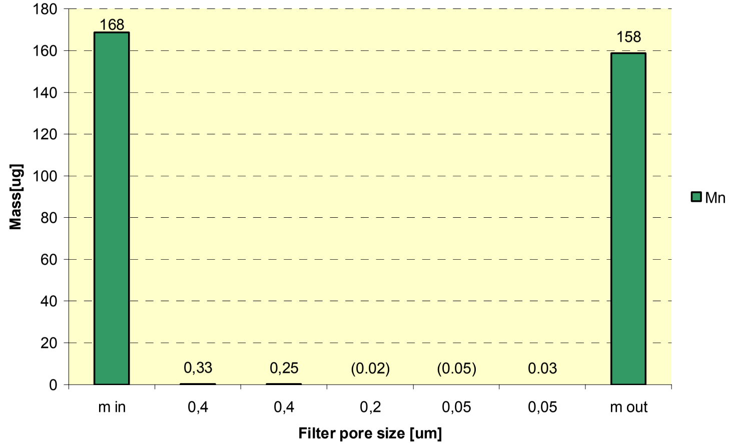


Figure 6-11. *Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).*

Result of colloid filtering using water sample from section 245.0-261.6 metres

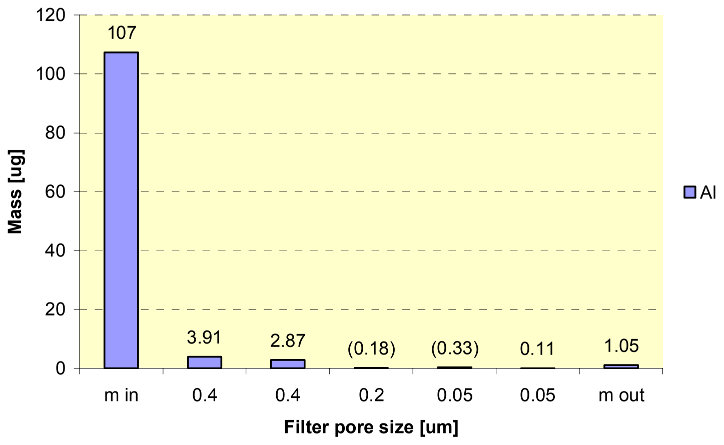


Figure 6-12. *Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).*

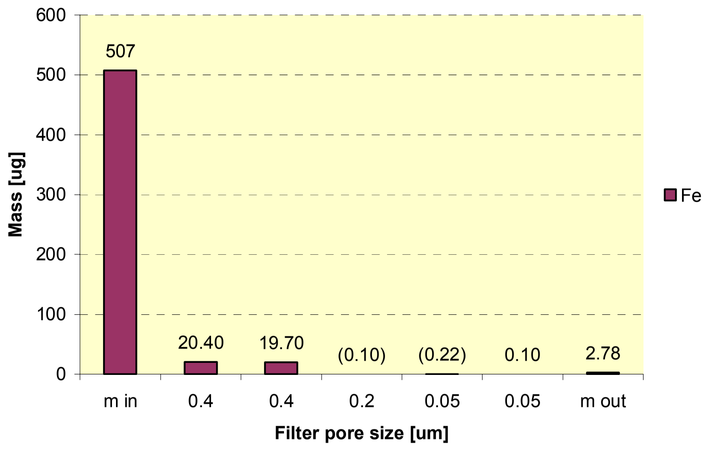


Figure 6-13. *Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).*

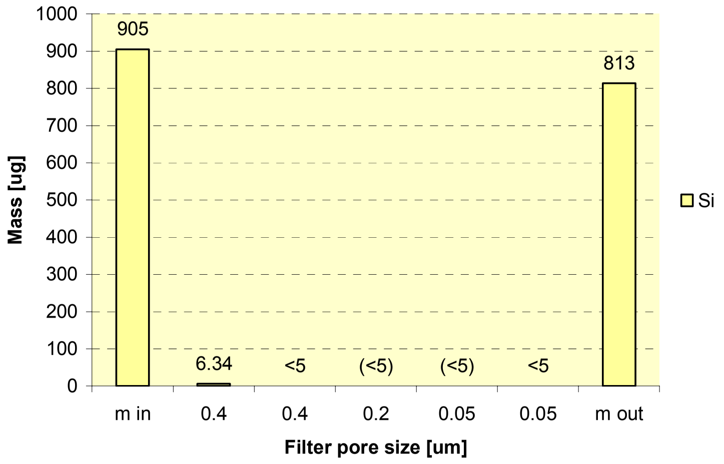


Figure 6-14. *Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

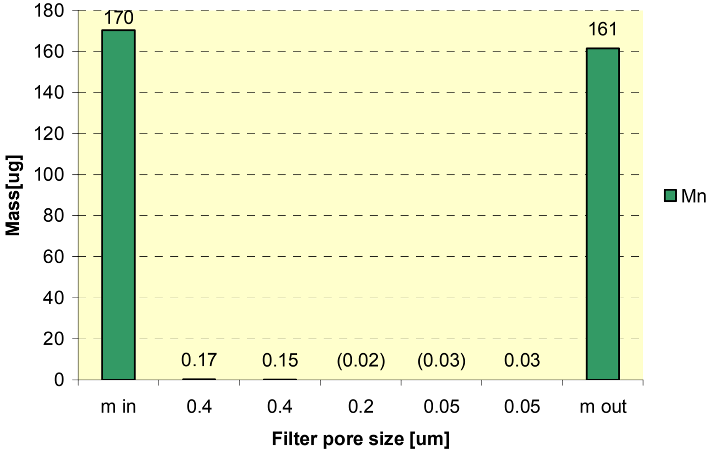


Figure 6-15. *Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).*

Result of colloid filtering using water sample from section 548.0-565.4 metres

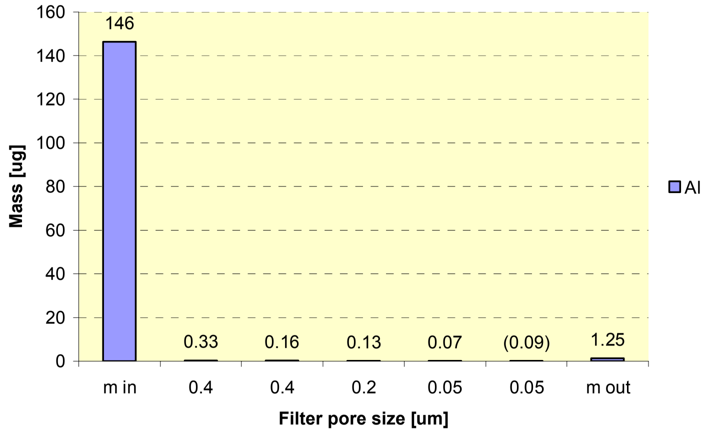


Figure 6-16. *Amount of aluminium entering the filter system (m in), in the filters and in the collecting container (m out).*

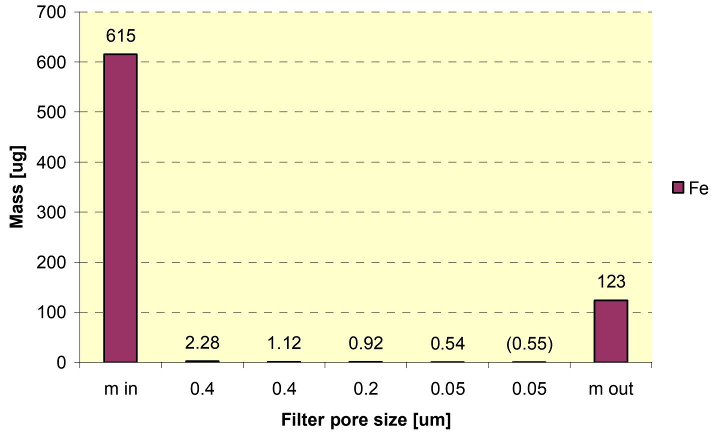


Figure 6-17. *Amount of iron entering the filter system (m in), in the filters and in the collecting container (m out).*

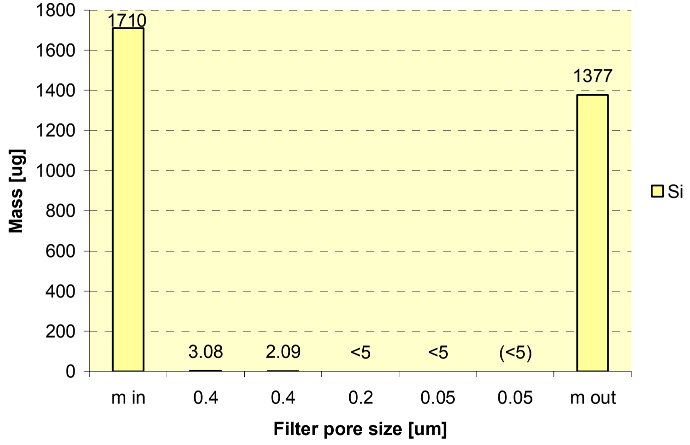


Figure 6-18. *Amount of silicon entering the filter system (m in), in the filters and in the collecting container (m out).*

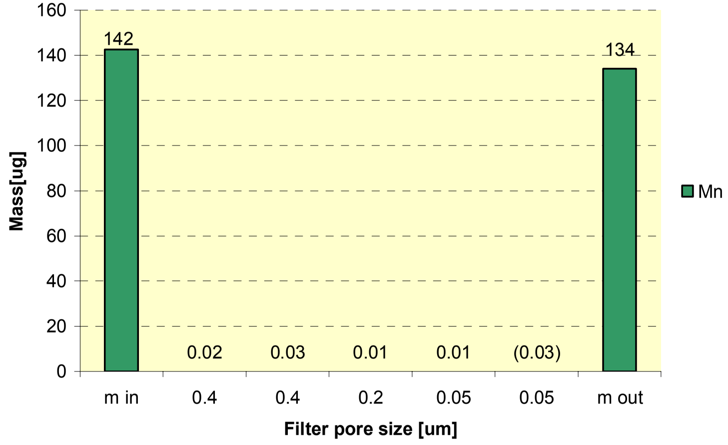


Figure 6-19. *Amount of manganese entering the filter system (m in), in the filters and in the collecting container (m out).*

6.6 Microbes

The results from the microbe investigation in sections 156.5–167.0, 245.0–254.6 and 548.0–565.4 m are reported in Appendix 1.

6.7 Dissolved gases

The results from the gas analyses in sections 156.5–167.0, 245.0–254.6 and 548.0–565.4 m are reported in Appendix 7, Table A7-5.

7 Conclusions

The main conclusions from the experimental results are:

- The targeted upper limit for flushing water content, 1%, was exceeded in all sections; 156.5–167.0 m (3%), 245.0–261.1 m (8%), 548.0–565.4 m (11%) and 586.0–596.7 m (36%). A high flushing water content can have an influence on the water composition.
- The pH (about 7.5) is similar in the sections.
- The electric conductivity increases with depth and the salinity (chloride concentration) of the water increases from section 156.5–167.0 m to section 548.0–565.4 m. This is expected since it generally is the case in deep boreholes.
- The redox potential measurements with surface Chemmac appear to be of very good quality. Almost all the electrodes stabilised at practically the same level (about –200 mV) in all three sections.
- The generally reducing conditions in the groundwater, as shown by the negative redox potentials, are supported by the presence of ferrous iron Fe (+II) at relatively high concentrations in all three borehole sections. Furthermore, the on-line measurements of dissolved oxygen show zero values and do not contradict this statement.
- The organic constituents in the groundwater are present as fulvic acids and possibly other low molecular weight organic acids (citric acid, oxalic acid etc).

8 References

/1/ **SKB, 2001.** Generellt genomförande program för platsundersökningar. SKB R 01-10. Svensk Kärnbränslehantering AB.

/2/ **Ask H, Morosini M, Samuelsson L-E, Stridsman H, 2003.** Drilling of cored borehole KSH01. SKB P-03-113. Svensk Kärnbränslehantering AB.

/3/ **Ask H, Samuelsson L-E, 2003.** Drilling of three flushing water wells, HSH01, HSH02 and HSH03. SKB P-03-114, Svensk Kärnbränslehantering AB.

/4/ **Wacker P, 2003.** Hydrochemical logging in KSH01A. SKB P-03-87. Svensk Kärnbränslehantering AB.

/5/ **Nilsson P, Gustafsson C, 2003.** Geophysical, radar and BIPS logging in borehole KSH01A, HSH01, HSH02 and HSH03. SKB P-03-15. Svensk Kärnbränslehantering AB.

/6/ **Aaltonen J, Gustafsson C, Nilsson P, 2003.** RAMAC and BIPS logging and deviation measurements in boreholes KSH01A, KSH01B and the upper part of KSH02. SKB P-03-73. Svensk Kärnbränslehantering AB.

/7/ **Nielsen U-T, Ringgaard J, 2003.** Geophysical borehole logging in borehole KSH01A, KSH01B and part of KSH02. SKB P-03-16. Svensk Kärnbränslehantering AB.

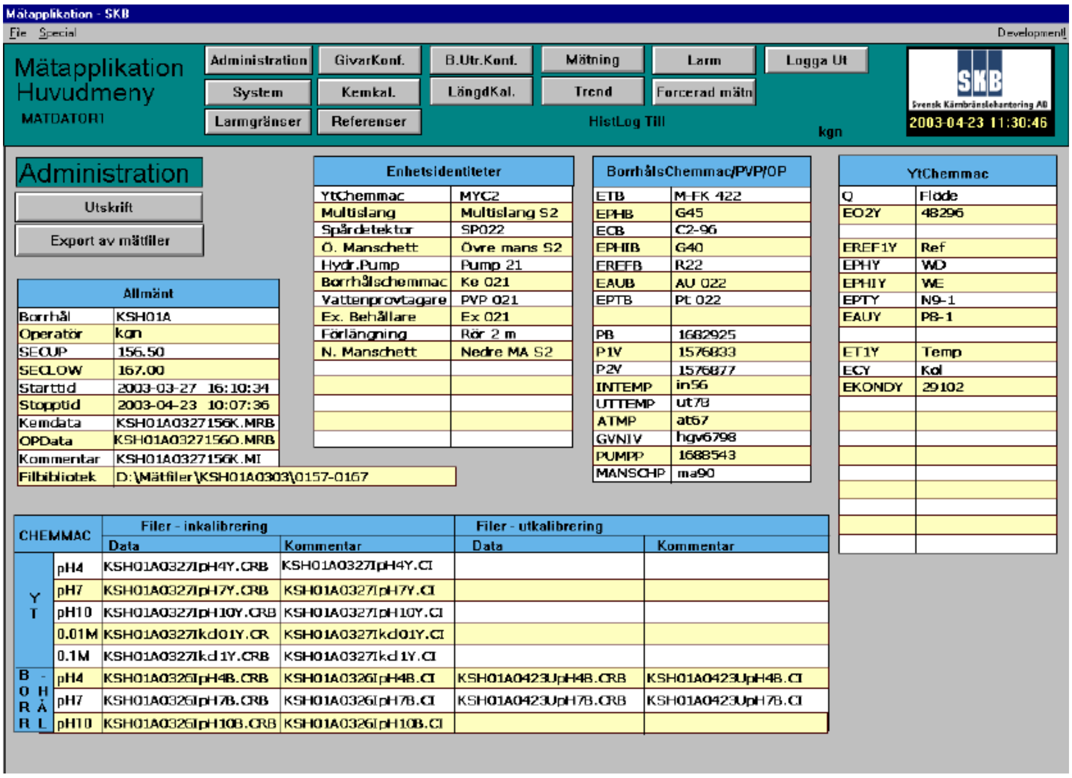
/8/ **Rouhiainen P, Pöllänen J, 2003.** Differential flow measurements in borehole KSH01A at Simpevarp. SKB P-03-70. Svensk Kärnbränslehantering AB.

/9/ **Pedersen K, Kalmus A, 2003.** Oskarshamn site investigation, Total numbers and metabolic diversity of micro organisms in borehole KSH01A, Results from three investigated sections 156,5–167 m, 245–261,6 m and section 548–565 m. SKB P-03-XX, Svensk Kärnbränslehantering AB.

Appendix 1

Downhole equipment

A1-1. Down-hole equipment in section 156.5-167.0 metres, administration.



Allmänt	
Borrhål	KSH01A
Operatör	kgn
SECUP	156.50
SECLOW	167.00
Starttid	2003-03-27 16:10:34
Stopptid	2003-04-23 10:07:36
Kemdata	KSH01A0327156K.MRB
OPData	KSH01A0327156O.MRB
Kommentar	KSH01A0327156K.MI
Filbibliotek	D:\Mätfiler\KSH01A0303\0157-0167

Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Spårdetektor	SP022
Ö. Manschett	Övre mans S2
Hydr.Pump	Pump 21
Borrhålschemmac	Ke 021
Vattenprovtagare	PVP 021
Ex. Behållare	Ex 021
Förlängning	Rör 2 m
N. Manschett	Nedre MA S2

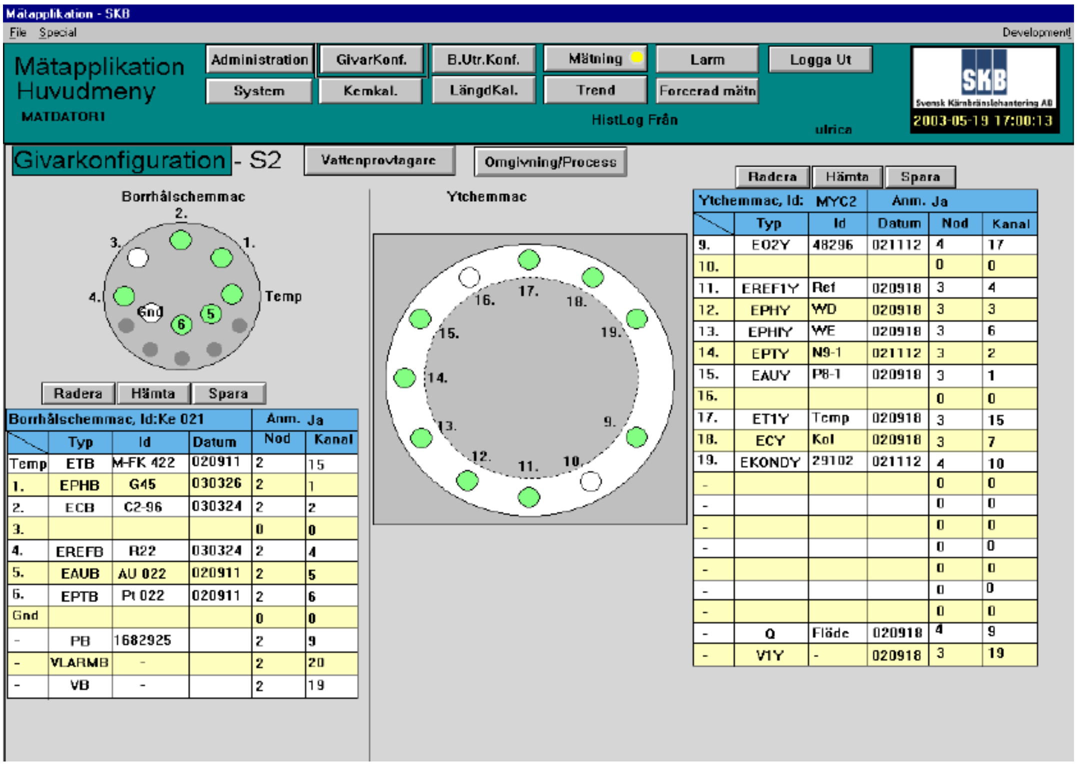
BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G45
ECB	C2-96
EPHIB	G40
EREFB	R22
EAUB	AU 022
EPTB	Pt 022
PB	1682925
P1V	1576833
P2V	1576877
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	hgv6798
PUMPP	1688543
MANSCHP	ma90

YtChemmac	
Q	Flöde
EO2Y	48296
EREF1Y	Ref
EPHY	WD
EPHIY	WE
EPTY	N9-1
EAUY	P8-1
ET1Y	Temp
ECY	Kol
EKONDY	29102

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KSH01A0327IpH4Y.CRB	KSH01A0327IpH4Y.CI		
	pH7	KSH01A0327IpH7Y.CRB	KSH01A0327IpH7Y.CI		
	pH10	KSH01A0327IpH10Y.CRB	KSH01A0327IpH10Y.CI		
	0.01M	KSH01A0327Ikd01Y.CR	KSH01A0327Ikd01Y.CI		
	0.1M	KSH01A0327Ikd1Y.CRB	KSH01A0327Ikd1Y.CI		
BORR-HÅL	pH4	KSH01A0326IpH4B.CRB	KSH01A0326IpH4B.CI	KSH01A0423UpH4B.CRB	KSH01A0423UpH4B.CI
	pH7	KSH01A0326IpH7B.CRB	KSH01A0326IpH7B.CI	KSH01A0423UpH7B.CRB	KSH01A0423UpH7B.CI
	pH10	KSH01A0326IpH10B.CRB	KSH01A0326IpH10B.CI		

Administration (2003-04-23).

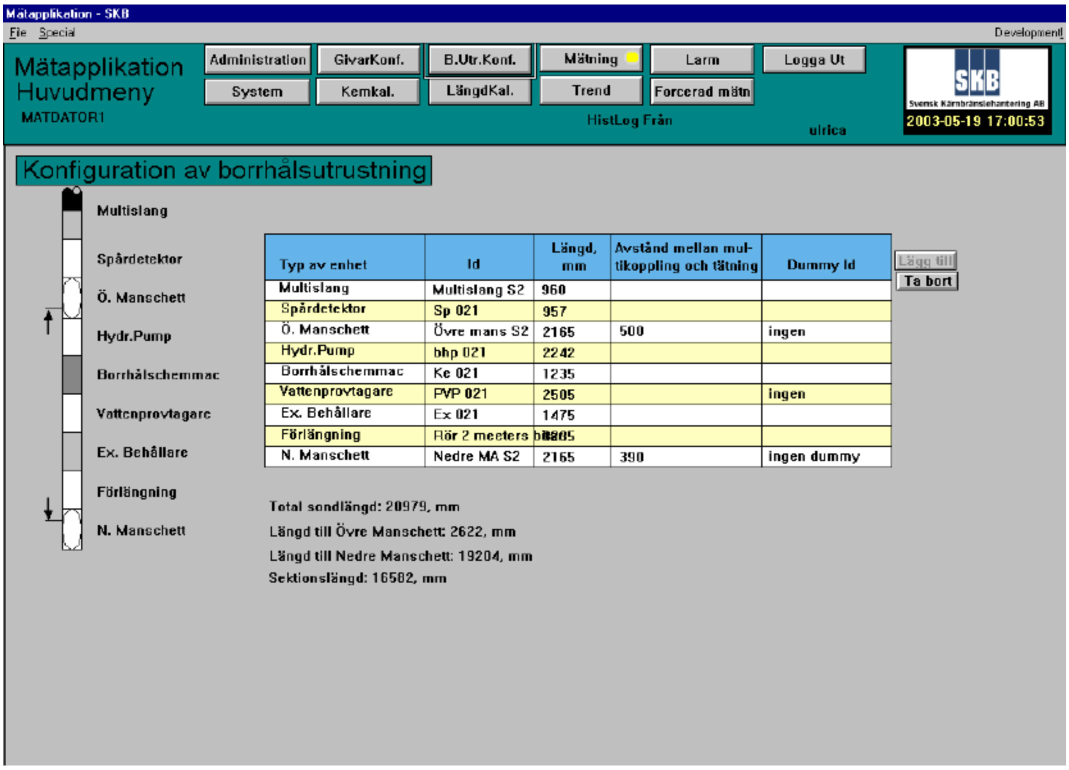
A1-2. Down-hole equipment in section 245.0-261.6 metres, chemmac configuration, configuration of borehole equipment and length calibration.



Borrhålschemmac, Id:Ke 021				Anm. Ja	
	Typ	Id	Datum	Nod	Kanal
Temp	ETB	M-FK 422	020911	2	15
1.	EPHB	G45	030326	2	1
2.	ECB	C2-96	030324	2	2
3.				0	0
4.	EREFB	R22	030324	2	4
5.	EAUB	AU 022	020911	2	5
6.	EPTB	Pt 022	020911	2	6
Gnd				0	0
-	PB	1682925		2	9
-	VLARMB	-		2	20
-	VB	-		2	19

Ytchemmac, Id:	MYC2		Anm. Ja		
	Typ	Id	Datum	Nod	Kanal
9.	EO2Y	48296	021112	4	17
10.				0	0
11.	EREF1Y	Ref	020918	3	4
12.	EPHY	WD	020918	3	3
13.	EPHIY	WE	020918	3	6
14.	EPTY	N9-1	021112	3	2
15.	EAUY	P8-1	020918	3	1
16.				0	0
17.	ET1Y	Temp	020918	3	15
18.	ECY	Kol	020918	3	7
19.	EKONDY	29102	021112	4	10
-				0	0
-				0	0
-				0	0
-				0	0
-				0	0
-				0	0
-				0	0
-	Q	Flöde	020918	4	9
-	V1Y	-	020918	3	19

Chemmac configuration (2003-05-19).



Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Spårdetektor	Sp 021	957		
Ö. Manschett	Övre mans S2	2165	500	ingen
Hydr.Pump	bhp 021	2242		
Borrhålschemmac	Ke 021	1235		
Vattenprovtagare	PVP 021	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	Rör 2 meeters b[illegible]	[illegible]		
N. Manschett	Nedre MA S2	2165	390	ingen dummy

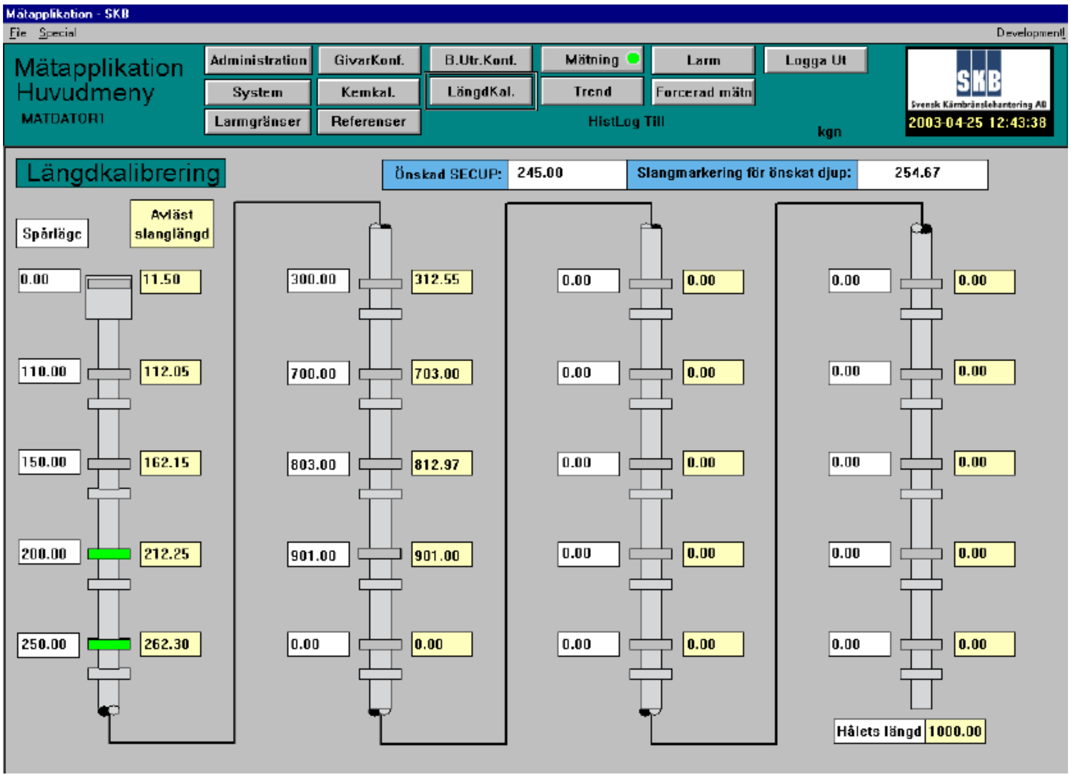
Total sondlängd: 20979, mm

Längd till Övre Manschett: 2622, mm

Längd till Nedre Manschett: 19204, mm

Sektionslängd: 16582, mm

Configuration of borehole equipment (2003-05-19).



Önskad SECUP: 245.00

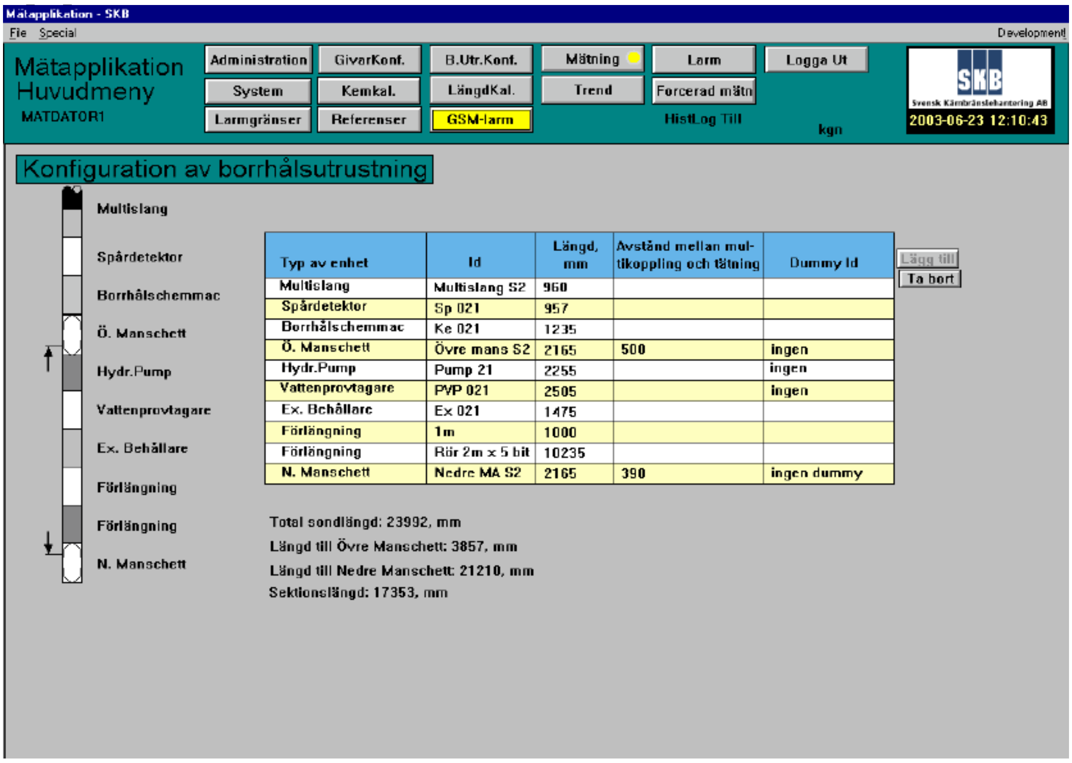
Slangmarkering för önskat djup: 254.67

Spårläge	Avläst slanglängd
0.00	11.50
110.00	112.05
150.00	162.15
200.00	212.25
250.00	262.30
300.00	312.55
700.00	703.00
803.00	812.97
901.00	901.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00

Hålets längd 1000.00

Length calibration (2003-04-25).

A1-3. Down-hole equipment in section 586.0-596.7 metres, configuration of borehole equipment.



Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Spårdetektor	Sp 021	957		
Borrhålschemmac	Ke 021	1235		
Ö. Manschett	Övre mans S2	2165	500	ingen
Hydr.Pump	Pump 21	2255		ingen
Vattenprovtagare	PVP 021	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	1m	1000		
Förlängning	Rör 2m x 5 bit	10235		
N. Manschett	Nedre MA S2	2165	390	ingen dummy

Total sondlängd: 23992, mm

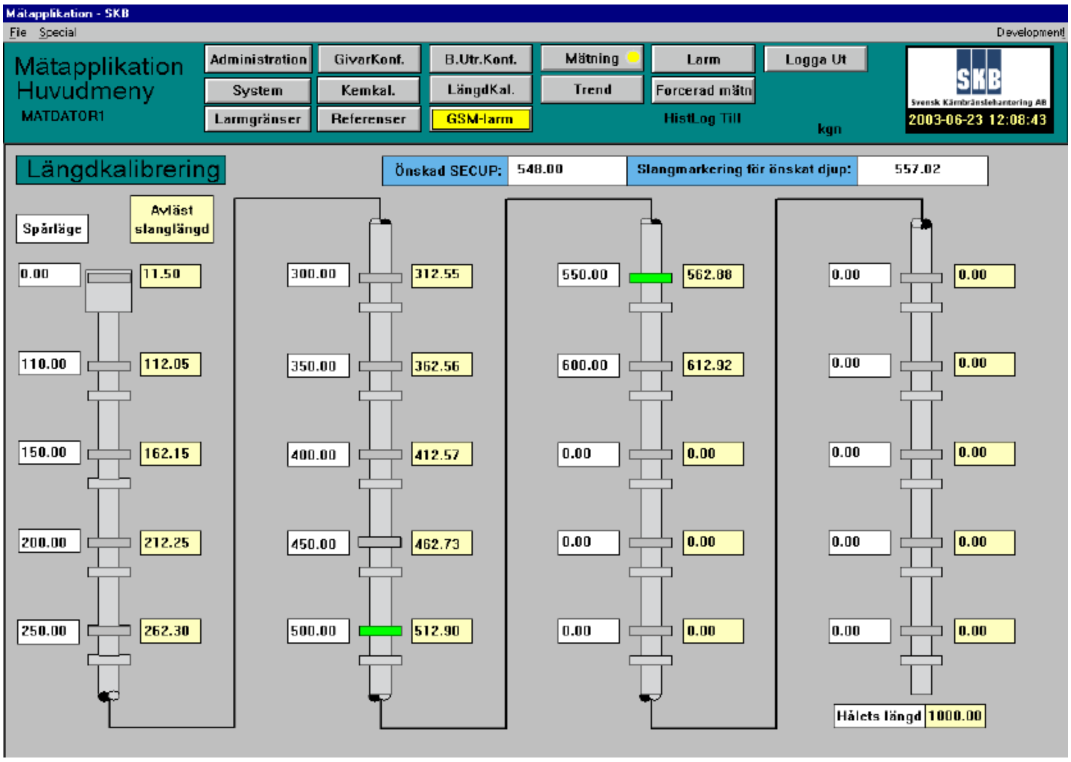
Längd till Övre Manschett: 3857, mm

Längd till Nedre Manschett: 21210, mm

Sektionslängd: 17353, mm

Configuration of borehole equipment (2003-06-23).

A1-4. Down-hole equipment in section 548.0-565.4 metres, administration (20030711, 20030826 and 20030916) configuration of borehole equipment and length calibration.



2003-06-23 12:08:43

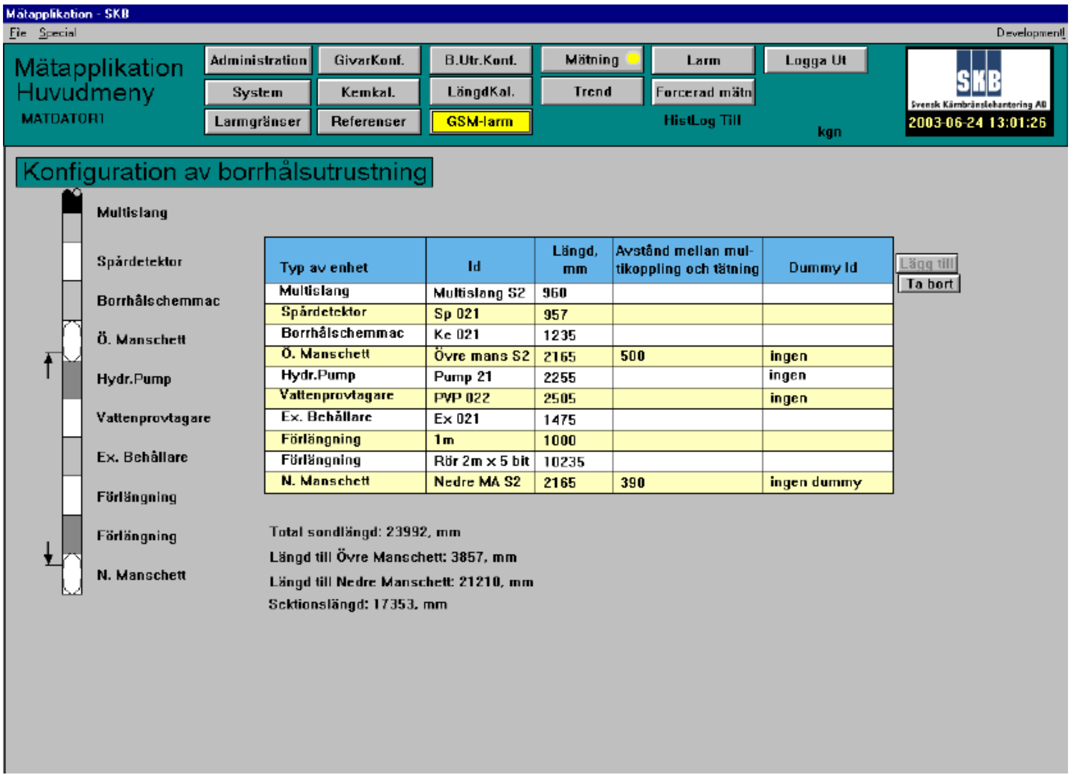
Önskad SECUP: 548.00

Slangmarkering för önskat djup: 557.02

Spårläge	Avläst slanglängd
0.00	11.50
110.00	112.05
150.00	162.15
200.00	212.25
250.00	262.30
300.00	312.55
350.00	362.56
400.00	412.57
450.00	462.73
500.00	512.90
550.00	562.88
600.00	612.92
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00
0.00	0.00

Hålets längd 1000.00

Length calibration (2003-06-23).



2003-06-24 13:01:26

Typ av enhet	Id	Längd, mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Spårdetektor	Sp 021	957		
Borrhålschemmac	Ke 021	1235		
Ö. Manschett	Övre mans S2	2165	500	ingen
Hydr.Pump	Pump 21	2255		ingen
Vattenprovtagare	PVP 022	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	1m	1000		
Förlängning	Rör 2m x 5 bit	10235		
N. Manschett	Nedre MA S2	2165	390	ingen dummy

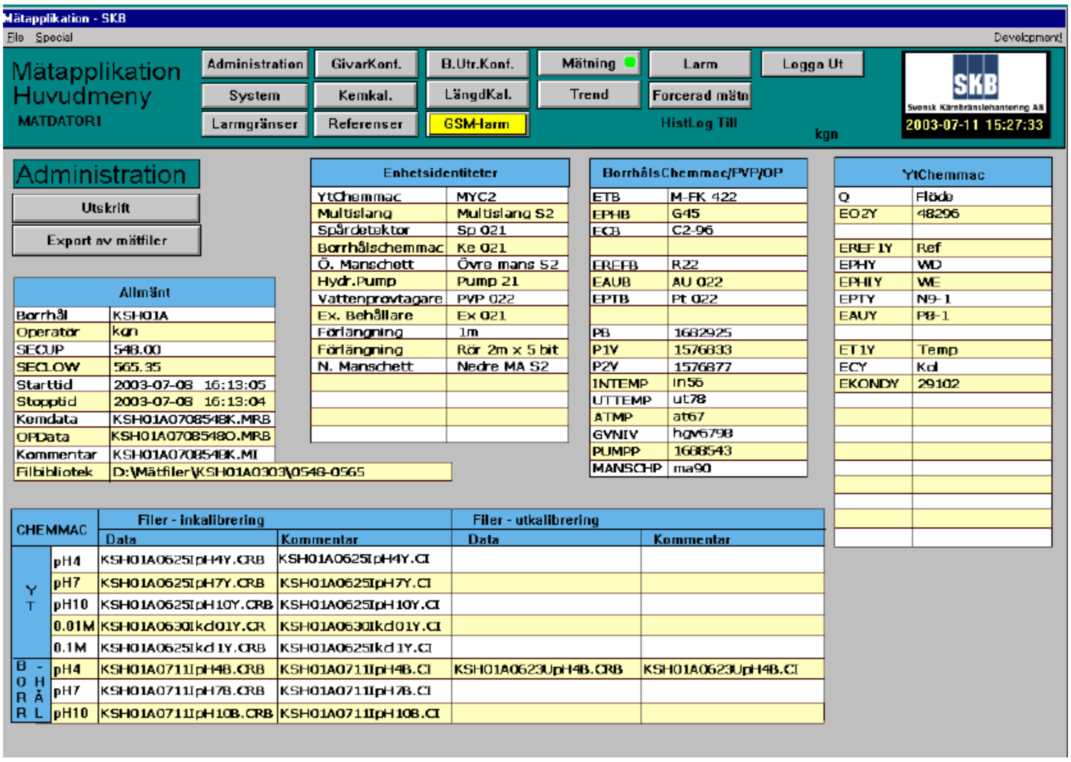
Total sondlängd: 23992, mm

Längd till Övre Manschett: 3857, mm

Längd till Nedre Manschett: 21210, mm

Sektionslängd: 17353, mm

Configuration of borehole equipment (2003-06-24).



Allmänt	
Borrhål	KSH01A
Operatör	kgn
SECUP	548.00
SECLOW	565.35
Starttid	2003-07-08 16:13:05
Stopptid	2003-07-08 16:13:04
Kemdata	KSH01A0708548K.MRB
OPData	KSH01A0708548O.MRB
Kommentar	KSH01A0708548K.MI
Filbibliotek	D:\Mätfiler\KSH01A0303\0548-0565

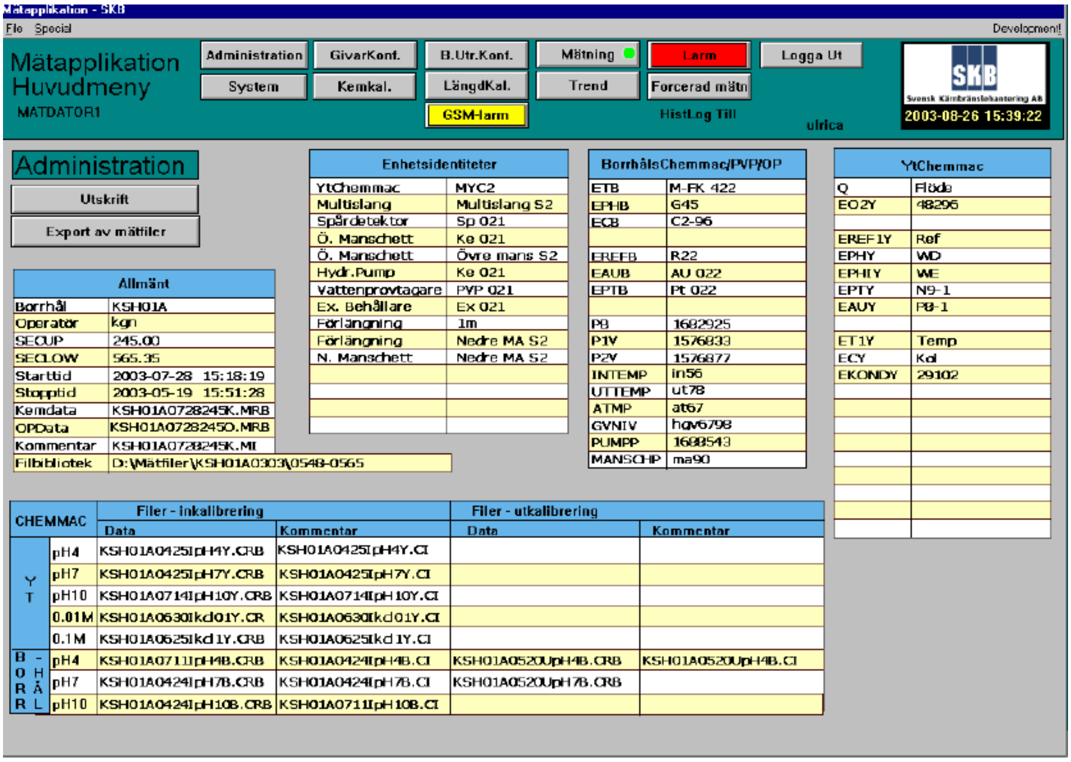
Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Spårdetektor	Sp 021
Borrhålschemmac	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Pump 21
Vattenprovtagare	PVP 022
Ex. Behållare	Ex 021
Förlängning	1m
Förlängning	Rör 2m x 5 bit
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G45
ECB	C2-96
EREFB	R22
EAUB	AU 022
EPTB	Pt 022
PB	1682925
P1V	1576833
P2V	1576877
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	hgv6798
PUMPP	1688543
MANSCHP	ma90

YtChemmac	
Q	Flöde
EO2Y	48296
EREF1Y	Ref
EPHY	WD
EPHIY	WE
EPTY	N9-1
EAUY	P8-1
ET1Y	Temp
ECY	Kol
EKONDY	29102

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KSH01A0625IpH4Y.CRB	KSH01A0625IpH4Y.CI		
	pH7	KSH01A0625IpH7Y.CRB	KSH01A0625IpH7Y.CI		
	pH10	KSH01A0625IpH10Y.CRB	KSH01A0625IpH10Y.CI		
	0.01M	KSH01A0630Ikd01Y.CR	KSH01A0630Ikd01Y.CI		
	0.1M	KSH01A0625Ikd1Y.CRB	KSH01A0625Ikd1Y.CI		
BORR - HÅL	pH4	KSH01A0711IpH4B.CRB	KSH01A0711IpH4B.CI	KSH01A0623UpH4B.CRB	KSH01A0623UpH4B.CI
	pH7	KSH01A0711IpH7B.CRB	KSH01A0711IpH7B.CI		
	pH10	KSH01A0711IpH10B.CRB	KSH01A0711IpH10B.CI		

Administration (2003-07-11).



Allmänt	
Borrhål	KSH01A
Operatör	kgn
SECUP	245.00
SECLOW	565.35
Starttid	2003-07-28 15:18:19
Stopptid	2003-05-19 15:51:28
Kemdata	KSH01A0728245K.MRB
OPData	KSH01A0728245O.MRB
Kommentar	KSH01A0728245K.MI
Filbibliotek	D:\Mätfiler\KSH01A0303\0548-0565

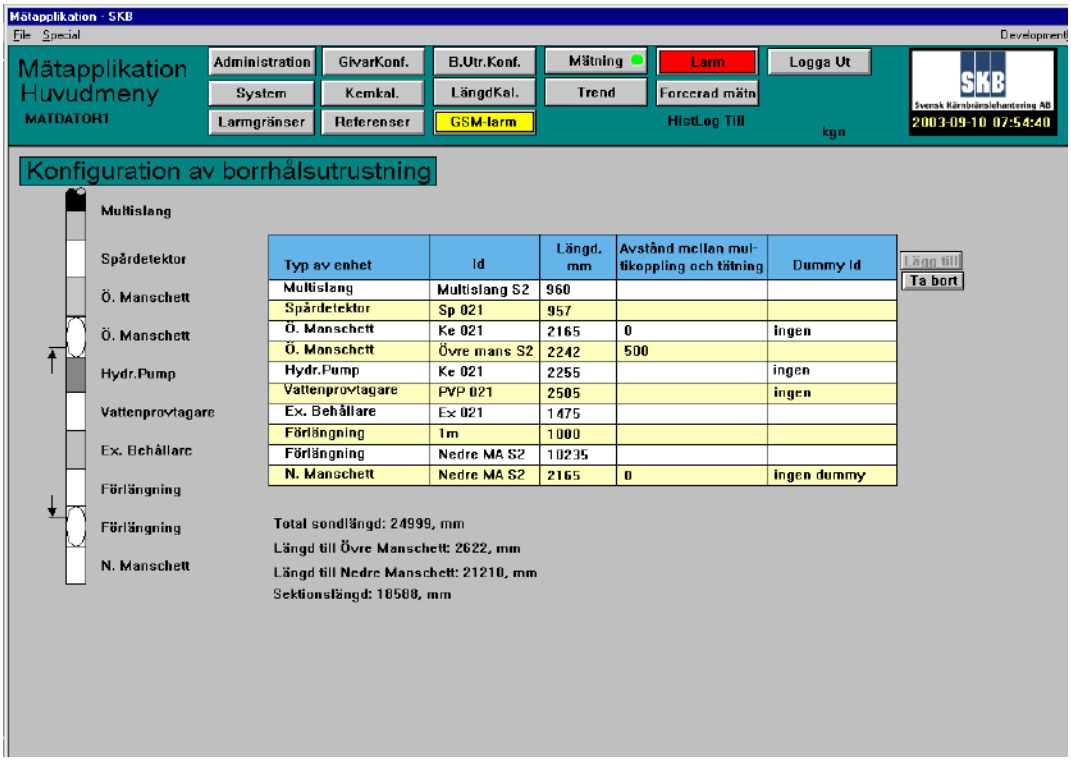
Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Spårdetektor	Sp 021
Ö. Manschett	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Ke 021
Vattenprovtagare	PVP 021
Ex. Behållare	Ex 021
Förlängning	1m
Förlängning	Nedre MA S2
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G45
ECB	C2-96
EREFB	R22
EAUB	AU 022
EPTB	Pt 022
PB	1682925
P1V	1576833
P2V	1576877
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIV	hgv6798
PUMPP	1688543
MANSCHP	ma90

YtChemmac	
Q	Flöde
EO2Y	48296
EREF1Y	Ref
EPHY	WD
EPHIY	WE
EPTY	N9-1
EAUY	P8-1
ET1Y	Temp
ECY	Kol
EKONDY	29102

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KSH01A0425IpH4Y.CRB	KSH01A0425IpH4Y.CI		
	pH7	KSH01A0425IpH7Y.CRB	KSH01A0425IpH7Y.CI		
	pH10	KSH01A0714IpH10Y.CRB	KSH01A0714IpH10Y.CI		
	0.01M	KSH01A0630Ikd01Y.CR	KSH01A0630Ikd01Y.CI		
	0.1M	KSH01A0625Ikd1Y.CRB	KSH01A0625Ikd1Y.CI		
BORR - HÅL	pH4	KSH01A0711IpH4B.CRB	KSH01A0424IpH4B.CI	KSH01A0520UpH4B.CRB	KSH01A0520UpH4B.CI
	pH7	KSH01A0424IpH7B.CRB	KSH01A0424IpH7B.CI	KSH01A0520UpH7B.CRB	
	pH10	KSH01A0424IpH10B.CRB	KSH01A0711IpH10B.CI		

Administration (2003-08-26).



Typ av enhet	Id	Längd. mm	Avstånd mellan multikoppling och tätning	Dummy Id
Multislang	Multislang S2	960		
Spårdetektor	Sp 021	957		
Ö. Manschett	Ke 021	2165	0	ingen
Ö. Manschett	Övre mans S2	2242	500	
Hydr.Pump	Ke 021	2255		ingen
Vattenprovtagare	PVP 021	2505		ingen
Ex. Behållare	Ex 021	1475		
Förlängning	1m	1000		
Förlängning	Nedre MA S2	10235		
N. Manschett	Nedre MA S2	2165	0	ingen dummy

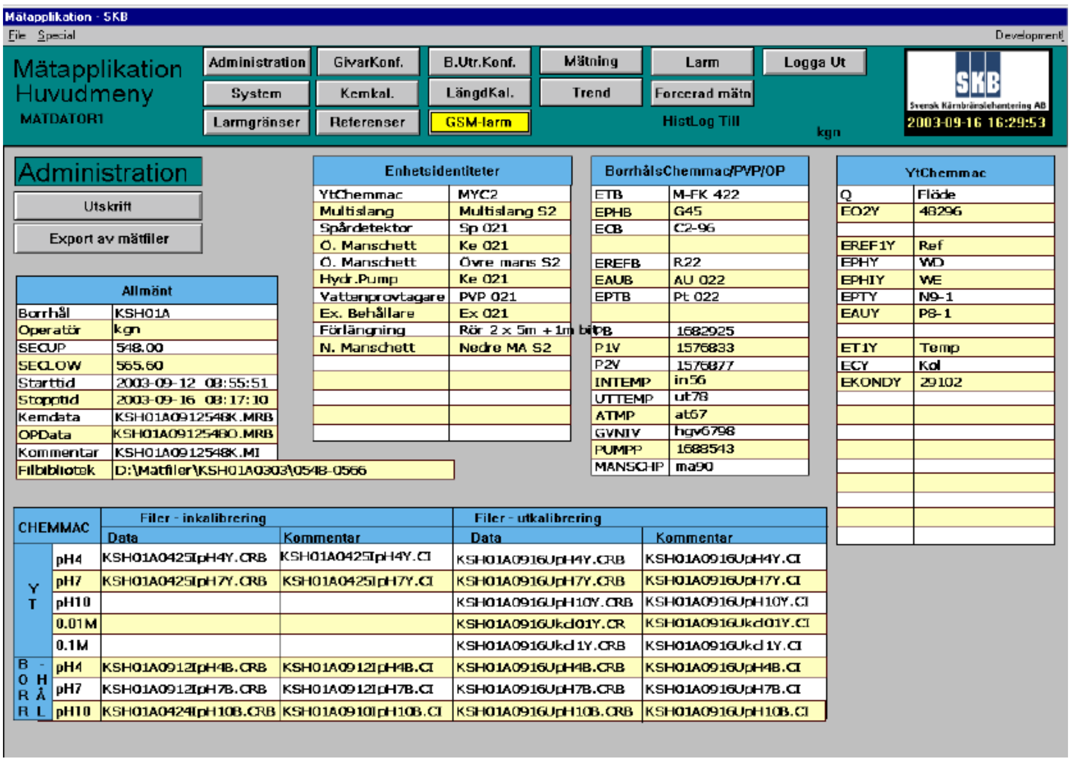
Total sondlängd: 24999, mm

Längd till Övre Manschett: 2622, mm

Längd till Nedre Manschett: 21210, mm

Sektionslängd: 18588, mm

Configuration of borehole equipment (2003-09-10)



Allmänt	
Borrhål	KSH01A
Operatör	kgn
SECUP	548.00
SECLOW	565.60
Starttid	2003-09-12 08:55:51
Stopptid	2003-09-16 08:17:10
Kemdata	KSH01A0912548K.MRB
OPData	KSH01A09125480.MRB
Kommentar	KSH01A0912548K.MI
Filbibliotek	D:\Mätfiler\KSH01A0303\0548-0566

Enhetsidentiteter	
YtChemmac	MYC2
Multislang	Multislang S2
Spårdetektor	Sp 021
Ö. Manschett	Ke 021
Ö. Manschett	Övre mans S2
Hydr.Pump	Ke 021
Vattenprovtagare	PVP 021
Ex. Behållare	Ex 021
Förlängning	Rör 2 x 5m + 1m bi
N. Manschett	Nedre MA S2

BorrhålsChemmac/PVP/OP	
ETB	M-FK 422
EPHB	G45
ECB	C2-96
EREFB	R22
EAUB	AU 022
EPTB	Pt 022
PB	1682925
P1V	1576833
P2V	1576877
INTEMP	in56
UTTEMP	ut78
ATMP	at67
GVNIY	hgv6798
PUMPP	1688543
MANSCHP	ma90

YtChemmac	
Q	Flöde
EO2Y	48296
EREF1Y	Ref
EPHY	WD
EPHIY	WE
EPTY	N9-1
EAUY	P8-1
ET1Y	Temp
ECY	Kol
EKONDY	29102

CHEMMAC		Filer - inkalibrering		Filer - utkalibrering	
		Data	Kommentar	Data	Kommentar
YT	pH4	KSH01A0425IpH4Y.CRB	KSH01A0425IpH4Y.CI	KSH01A0916UpH4Y.CRB	KSH01A0916UpH4Y.CI
	pH7	KSH01A0425IpH7Y.CRB	KSH01A0425IpH7Y.CI	KSH01A0916UpH7Y.CRB	KSH01A0916UpH7Y.CI
	pH10			KSH01A0916UpH10Y.CRB	KSH01A0916UpH10Y.CI
	0.01M			KSH01A0916Ukd01Y.CR	KSH01A0916Ukd01Y.CI
	0.1M			KSH01A0916Ukd1Y.CRB	KSH01A0916Ukd1Y.CI
BORR-HÅL	pH4	KSH01A0912IpH4B.CRB	KSH01A0912IpH4B.CI	KSH01A0916UpH4B.CRB	KSH01A0916UpH4B.CI
	pH7	KSH01A0912IpH7B.CRB	KSH01A0912IpH7B.CI	KSH01A0916UpH7B.CRB	KSH01A0916UpH7B.CI
	pH10	KSH01A0424IpH10B.CRB	KSH01A0910IpH10B.CI	KSH01A0916UpH10B.CRB	KSH01A0916UpH10B.CI

Administration (2003-09-16).

Sampling and analysis methods

Table A2-1. Overview of general sample handling routines and analysis methods.

Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Anions 1	HCO_3 pH(lab) cond (lab)	Plastic	250	Yes (not in the field)	No	Titration Pot. meas, Cond. meas	Mobile field lab. Alcontrol	The same day – maximum 24 hours
Anions 2	Cl, SO_4, Br^-, F^-, I^-	Plastic	100	Yes (not in the field)	No	Titration (Cl^-) IC (Cl^-, SO4, Br^-, F^-) ISE (F^-)	Äspö:s chemistry lab. Alcontrol	Not critical (month)
	Br, I	Plastic	100	Yes (not in the field)	No	ICP MS	Paavo Ristola OY SGAB Analytica,	Not critical (month)
Cations, Si and S according to SKB class 3	Na, K, Ca, Mg, S(tot), Si(tot), Li, Sr	Plastic (at low conc. acid washed bottles)	100	Yes (not in the field)	Yes (not in the field, 1 mL HNO_3)	ICP-AES ICP-MS	SGAB Analytica, SLU, Umeå	Not critical (month)
Cations, Si and S according to SKB class 4 and 5	Na, K, Ca, Mg, S(tot), Si(tot), Fe, Mn, Li, Sr	Plastic (Acid washed)	100	Yes (immediately in the field)	Yes (1mL HNO_3)	ICP-AES ICP-MS	SGAB Analytica, SLU, Umeå	Not critical (month)
Fe(II), Fe(tot)	Fe(II), Fe(tot)	Plastic (Acid washed)	500	Yes	Yes (5 mL HCl))	Spectrophotometry Ferrozine method	Mobile field lab.	As soon as possible the same day
Hydrogen sulphide	HS–	Glass (Winkler)	About 120×2	No	Ev 1 mL 1 M NaOH+ 1 mL 1M ZnAc	Spectrophotometry	Alcontrol Äspö:s chemistry lab.	Immediately or if conserved, a few days
Nutrient salts	NO_2, NO_3+NO_2, NH_4, PO_4	Plastic	250	No	No	Spectrophotometry	Äspö:s chemistry lab. Alcontrol	Maximum 24 hours
Environmental metals	Al, As, Ba, B, Cd, Co, Cr, Cu, Hg, Mo, Ni, P, Pb, V, Zn	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	SGAB Analytica, Alcontrol	Not critical (month)
Lantanoids, U, Th and so on	Sc, Rb, Y, Zr, I, Sb, Cs, La, Hf, Tl, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, U, Th	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP-AES ICP-MS	SGAB Analytica, Alcontrol	Not critical (month)
Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Dissolved organic Carbon, dissolved inorganic Carbon	DOC, DIC	Plastic	250 25	Yes	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time

Total organic Carbon	TOC	Plastic	250 25	No	Frozen, transported in isolated bag	UV oxidation, IR Carbon analysator Shimadzu TOC5000	Paavo Ristola OY Dept. of System ecology, SU	Short transportation time
Environmental isotopes	^{2}H, ^{18}O	Plastic	100	No	– –	MS	IFE	Not critical (month)
Tritium,	^{3}H (enhanced.)	Plastic (dry bottle)	500	No	–	LSC	Univ. Of Waterloo	Not critical (month)
Chlorine-37	Chlorine-37	Plastic	100	No	–	ICP MS		
Carbon isotopes	^{13}C, ^{14}C	Glass (brown)	100×2	No	–	(A)MS	Univ. Of Waterloo	A few days
Sulphur isotopes	^{34}S	Plastic	500 –1000	Yes	–	Combustion, ICP MS	IFE	No limit
Strontium-isotopes	^{87}Sr/^{86}Sr	Plastic	100	Yes	–	TIMS	IFE	Days or Week
Uranium and Thorium isotopes	^{234}U, ^{235}U, ^{238}U, ^{232} Th, ^{230}Th,	Plastic	50	Nej	–	Chemical separat. Alfa/ gamma spectrometry	IFE	No limit
Boron isotopes	^{10}B	Plastic	100	Yes	Yes (1 mL HNO_3)	ICP – MS	SGAB Analytica	No limit
Radon and Radium isotopes	^{222}Rn, ^{226}Ra	Plastic	500	No	No	EDA, RD-200	IFE	Immediate transport
Dissolved gas (content and composition)	Ar, N_2, CO_2, O_2, CH_4, H_2, CO, C_2H_2, C_2H_4, C_2H_6, C_3H_8	Cylinder of stainless steel	200	No	No	GC	Paavo Ristola OY	Immediate transport
Colloids	Filter series and fractionation (see below)	Polycarbonate filter	0.45, 0.2 and 0.05 µm	–	N_2 atmosphere	ICP-AES ICP-MS	SGAB Analytica	Immediate transport
Humic and fulvic acids	Fractionation	Fractions are collected in plastic bottles	250	–	N_2 atmosphere	UV oxidation, IR (DOC)	Paavo Ristola OY	Immediate transport
Archive samples with acid	–	Plast (washed in acid)	100×2 **	Yes	Yes (1 mL HNO_3)	–	–	Storage in freeze container
Archive samples without acid	–	Plastic	250×2 **	Yes	No	–	–	Storage in freeze container
Component group	Component/ element	Sample container (material)	Volume (mL)	Filtering	Preparation/ Conservation*	Analysis method	Laboratory***	Analysis within – or delivery time to lab.
Carbon isotopes in humic and fulvic acids	^{13}C, ^{14}C	DEAE cellulose (anion exchanger)	–	–	–	(A)MS	The Ångström laboratory, Uppsala	A few days

* Suprapur acid is used for conservation of samples.

** Minimum

*** Full name and address is given in Table A2-3.

Abbreviations and definitions:

IC	Ion chromatograph
ISE	Ion selective electrode
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
INAA	Instrumental Neutron Activation Analysis
MS	Mass Spectrometry
LSC	Liquid Scintillation Counting
(A)MS	(Accelerator) Mass Spectrometry
GC	Gas Chromatography

Table A2-2. Reporting limits and measurement uncertainties.

Component	Method	Reporting limits or range	Unit	Measurement uncertainties[1]	"Total" uncertainties[2]
HCO_3	Alkalinity titration	1	mg/L	4%	Time delay affects the results
Cl^-	Mohr- titration	> 70	mg/L	5%	< 10%
Cl^-	IC	1–100		6%	20%
SO_4	IC	1	mg/L	10%	20%
Br^-	IC	0.2	mg/L	9%	30%
Br^-	ICP	0.001		15%	
F^-	IC	0.1	mg/L	10%	20%
F^-	Potentiometric	–		–	
I^-	ICP	0.001	mg/L	15%	20%
Na	ICP	0.1	mg/L	4%	10%
K	ICP	0.4	mg/L	6%	20%
Ca	ICP	0.1	mg/L	4%	10%
Mg	ICP	0.09	mg/L	4%	10%
S(tot)	ICP	0.160	mg/L	21%	20%
Si(tot)	ICP	0.03	mg/L	4%	15%
Sr	ICP	0.002	mg/L	4%	10%
Li	ICP	0.2 (Salt ≤ 0.4% , 520 mS/m) 2 (Salt ≤3.5% , 3810 mS/m)	mg/L	10%	20%
^{2}H	MS	–	‰ dev SMOW	±1.0‰	–
^{18}O	MS	–	‰ dev SMOW	±.2‰	–
^{3}H	LSC	0.8 eller 0.1	TU	0.8	–
^{37}Cl	ICP MS	0.2‰ (20 mg/L)	SMOC	–	–
^{13}C	A (MS)	–	PDB	–	–
^{14}C pmc	A (MS)	–	PMC	–	–
^{34}S	ICP MS	0.2‰	CDT	0.3‰	–
$^{87}Sr/^{86}Sr$	TIMS	–	No unit	± 0.000015	–
$^{10}B/^{11}B$	ICP MS	–	No unit	± 0.001	

[1] Measurement uncertainty reported by consulted laboratory

[2] " Total" uncertainty estimated by experience (includes sampling and sample handling)

Table A2-3. Consulted laboratories, full name and address.

Äspö waterchemical laboratory (SKB)
Mobile field laboratory, Oskarshamn (SKB)

Inainööritoimisto
Paavo Ristola Oy
Teollisuus-ja
Voimalaitoskemia
Rajantorpantie 8, C-talo
01600 Vantaa
FINLAND

Dept. of System ecology
Stockholm University
10691 Stockholm

Analytica AB
Aurorum 10
977 75 Luleå
(Nytorpsvägen 16
Box 511
183 25 Täby)

Environmental Isotope Laboratory
Dep. Of earth sciences
University of Waterloo
Waterloo, Ontario
N2L 3G1 CANADA

Institutt for energiteknik (IFE)
Insituttveien 18
P.O Box 40
2027 Kjeller
NORGE

Alcontrol Nordic AB
Box 905
531 19 Lidköping

The Ångström laboratory
Box 534
Se-751 21 Uppsala

Environmental research laboratory (SLU), Luleå

Alcontrol
Box 1083
581 10 Linköping

Appendix 3

Chemmac measurement in section 156.5–167.0 m

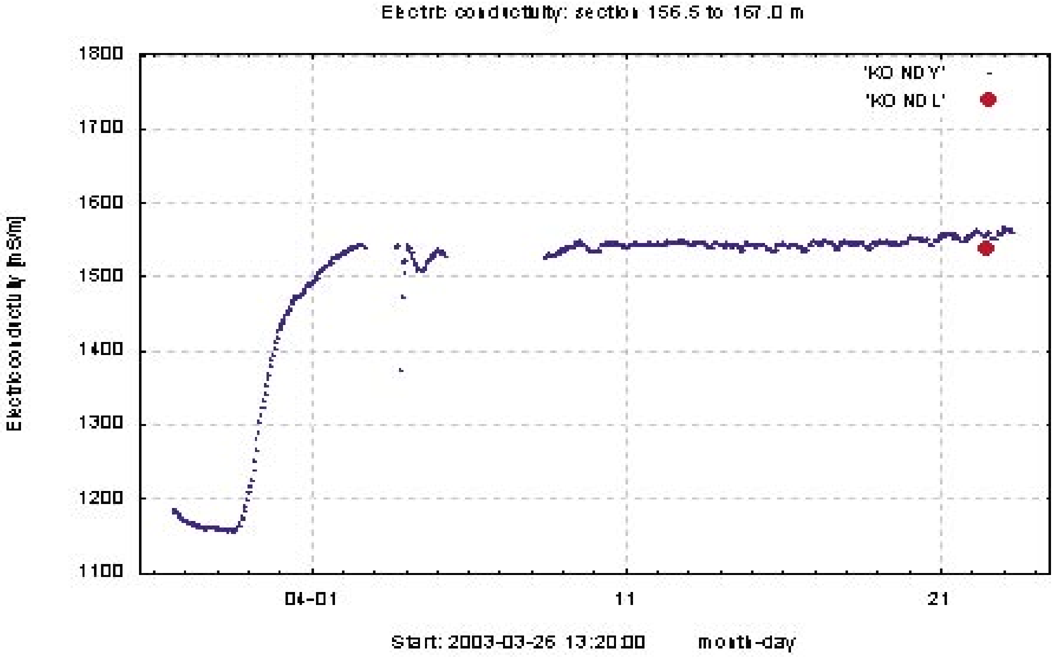


Figure A3-1. *Electric conductivity measurement in the surface measurement cell (KONDY). The electric conductivity measured in the last collected sample (KONDL) is given for comparison.*

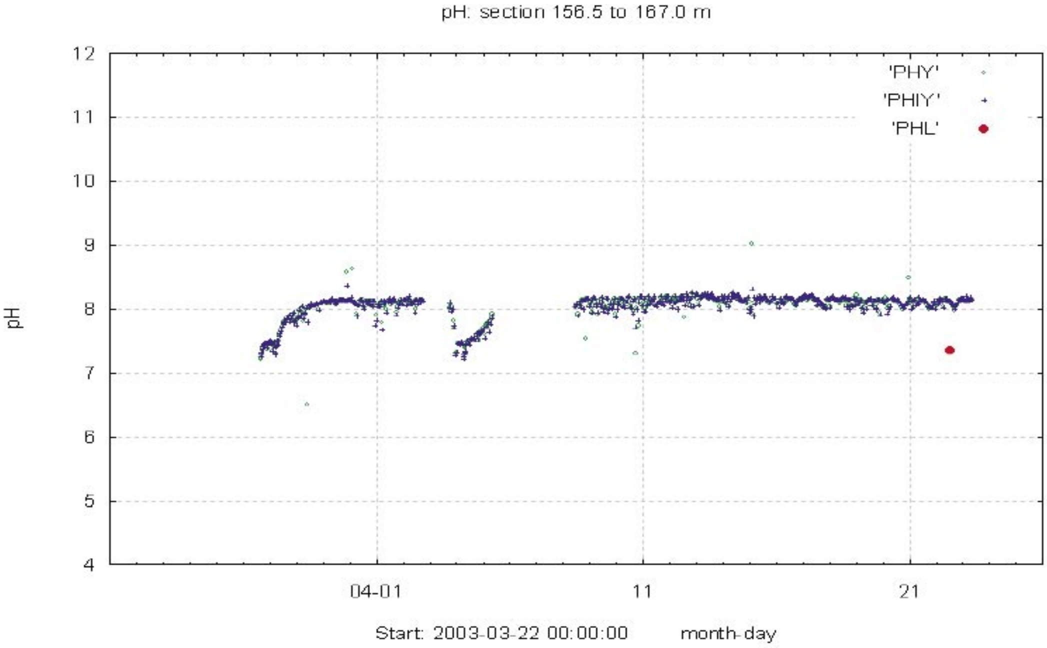


Figure A3-2. *Measurements of pH by two glass electrodes at the surface (PHY and PHIY). The laboratory pH in the last collected sample (PHL) is given for comparison.*

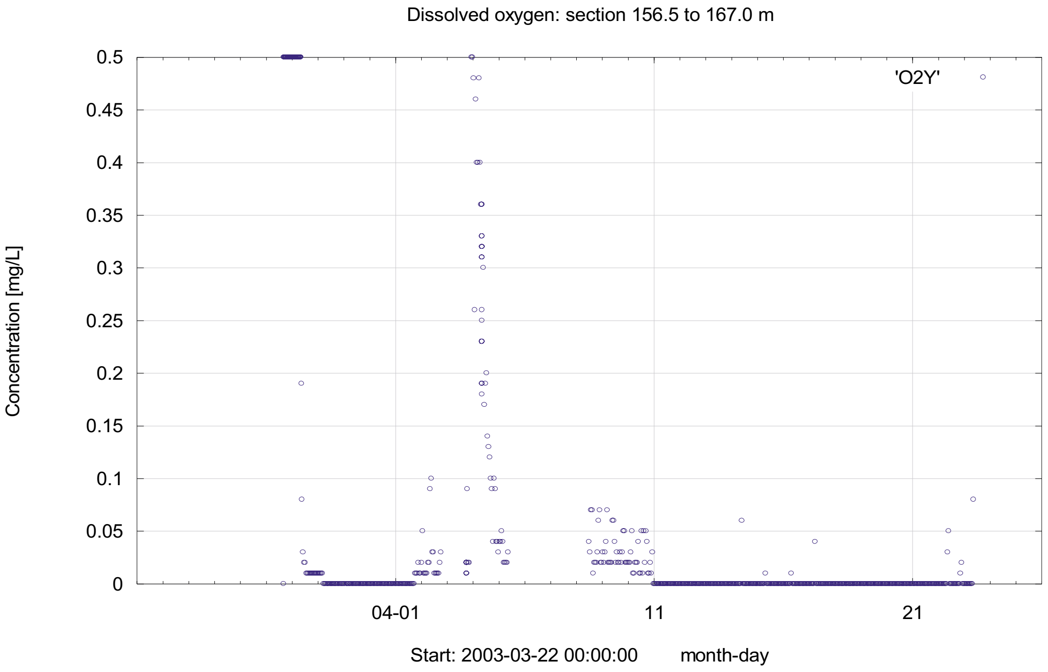


Figure A3-3. *Dissolved oxygen measurement (O2Y) in the surface measurement cell.*

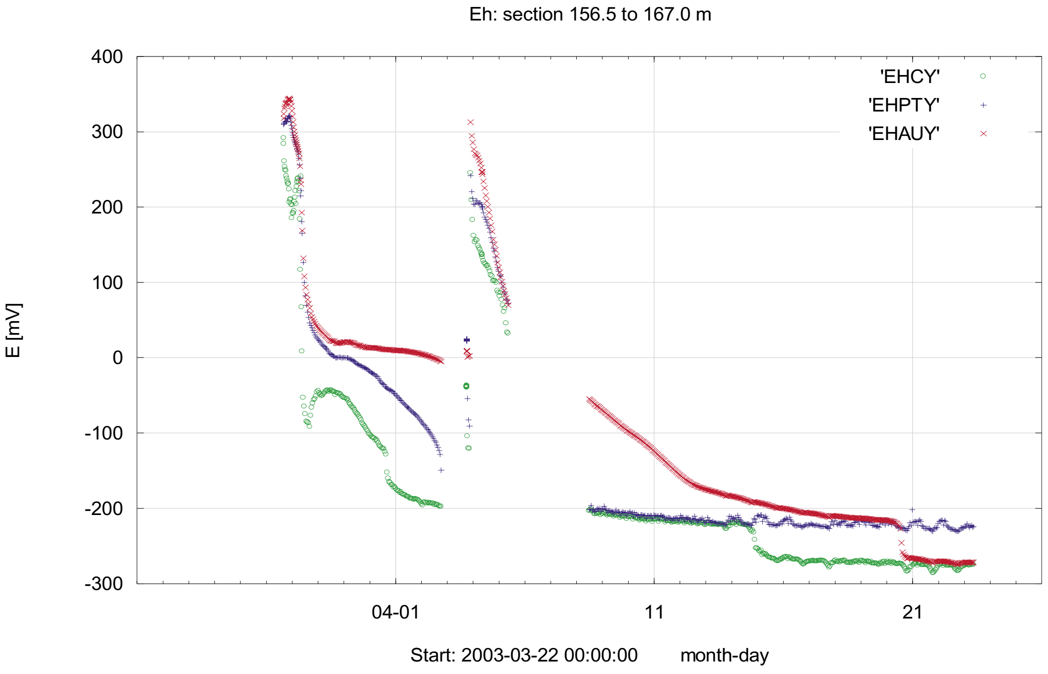


Figure A3-4. *Redox potental measurements (Eh) by platinum, gold and glassy carbon electrodes at the surface (EHPTY, EHAUY and EHCY).*

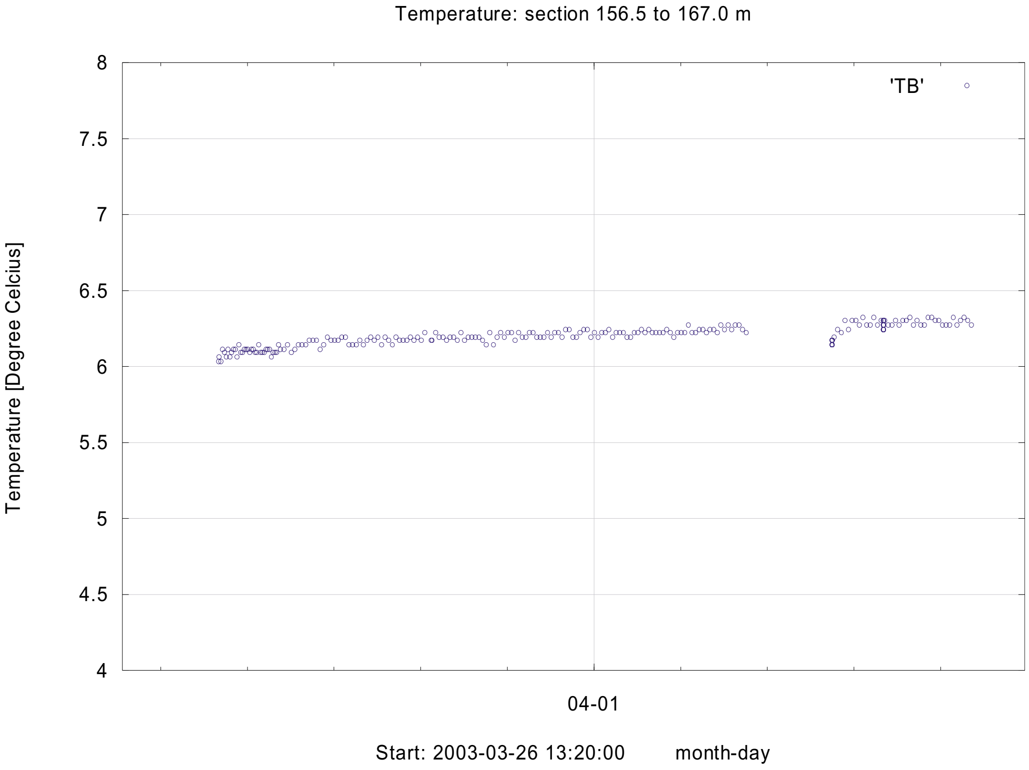


Figure A3-5. *Temperature of the groundwater in the borehole section (TB).*

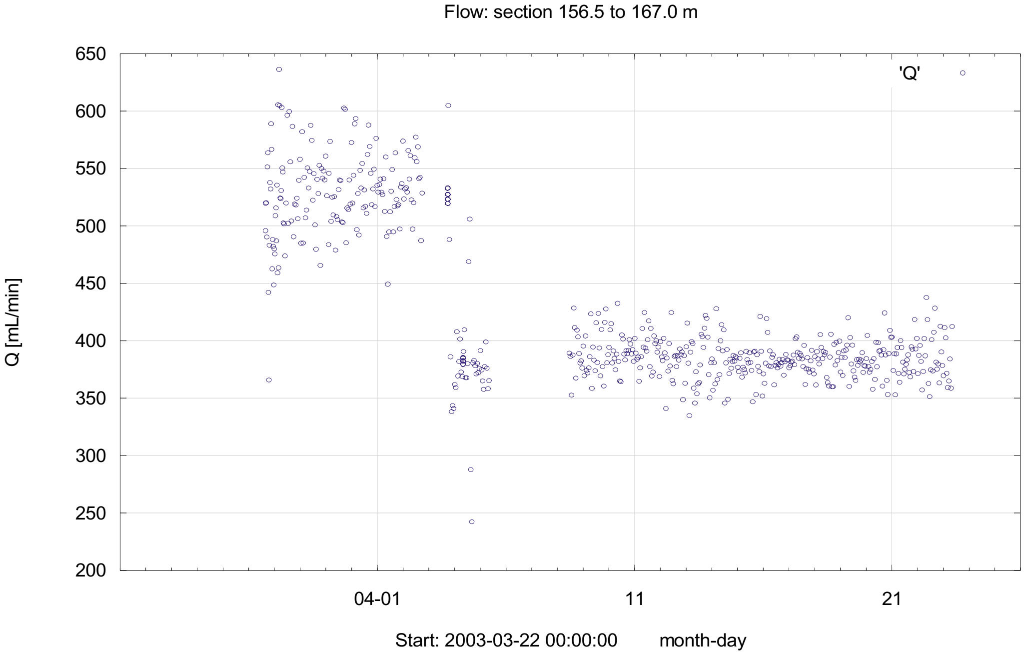


Figure A3-6. *Variation in flow rate during the pumping and measurement period.*

Appendix 4

Chemmac measurement in section 245.0–261.6 m

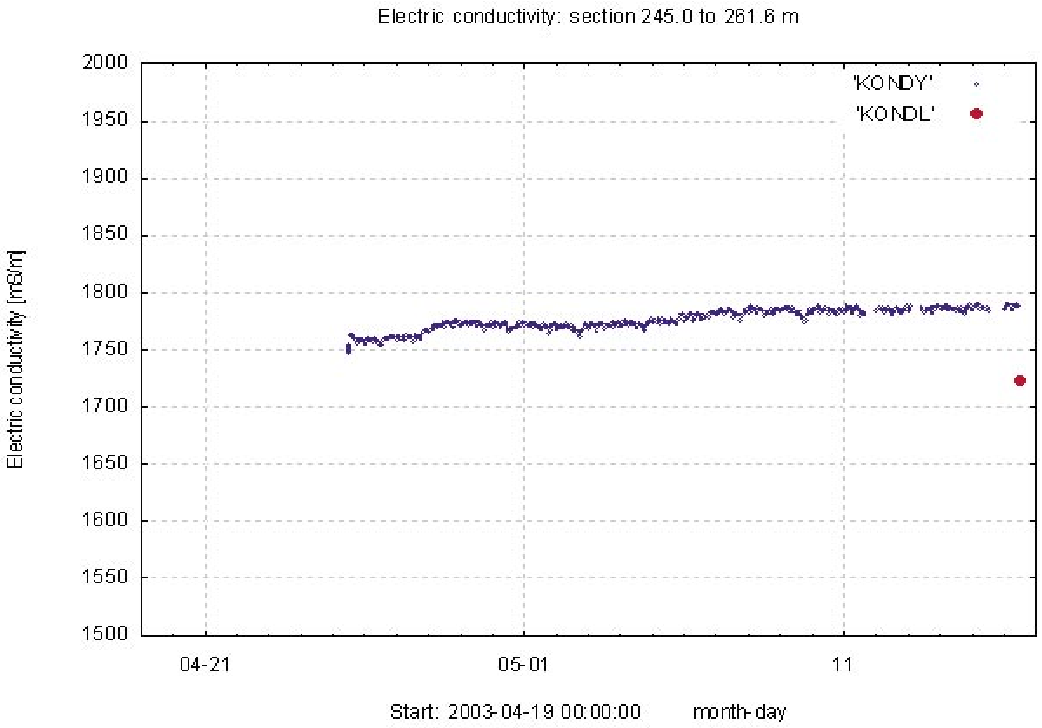


Figure A4-1. *Electric conductivity measurement in the surface measurement cell (KONDY). The electric conductivity measured in the last collected sample (KONDL) is given for comparison.*

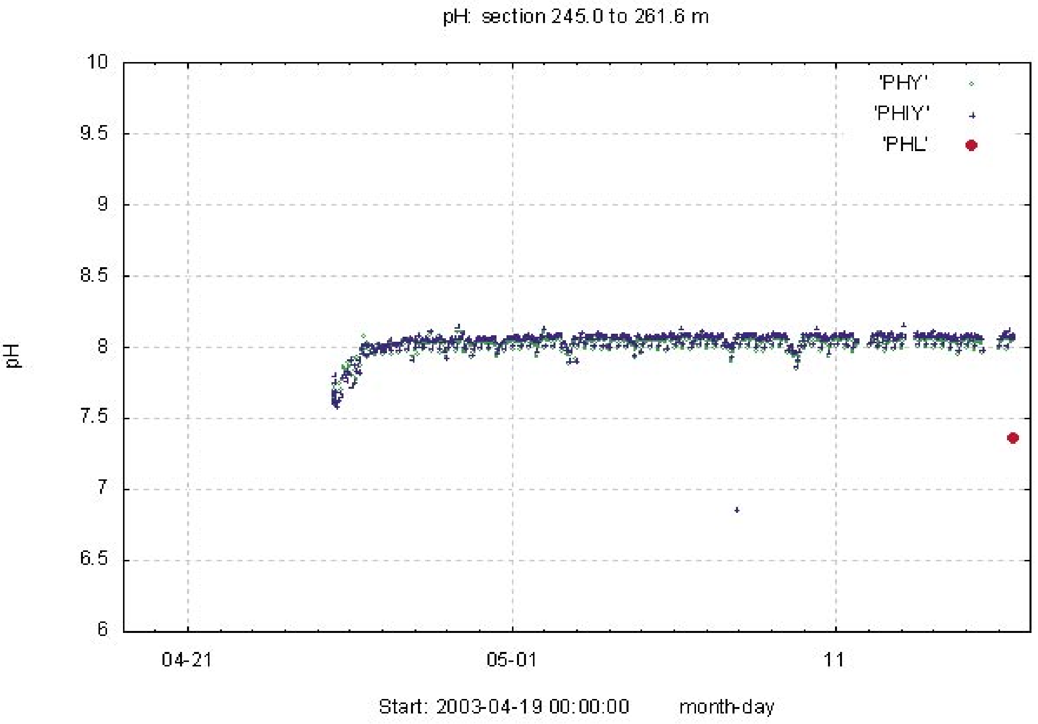


Figure A4-2. *Measurements of pH by two glass electrodes at the surface (PHY and PHIY). The laboratory pH in the last collected sample (PHL) is given for comparison.*

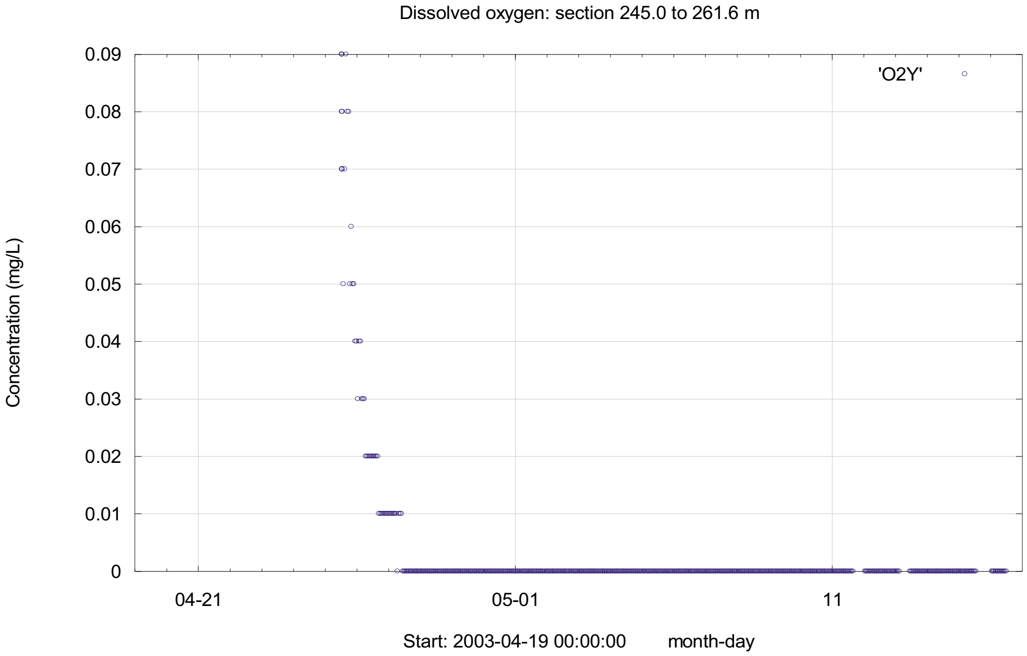


Figure A4-3. Dissolved oxygen measurement (O2Y) in the surface measurement cell.

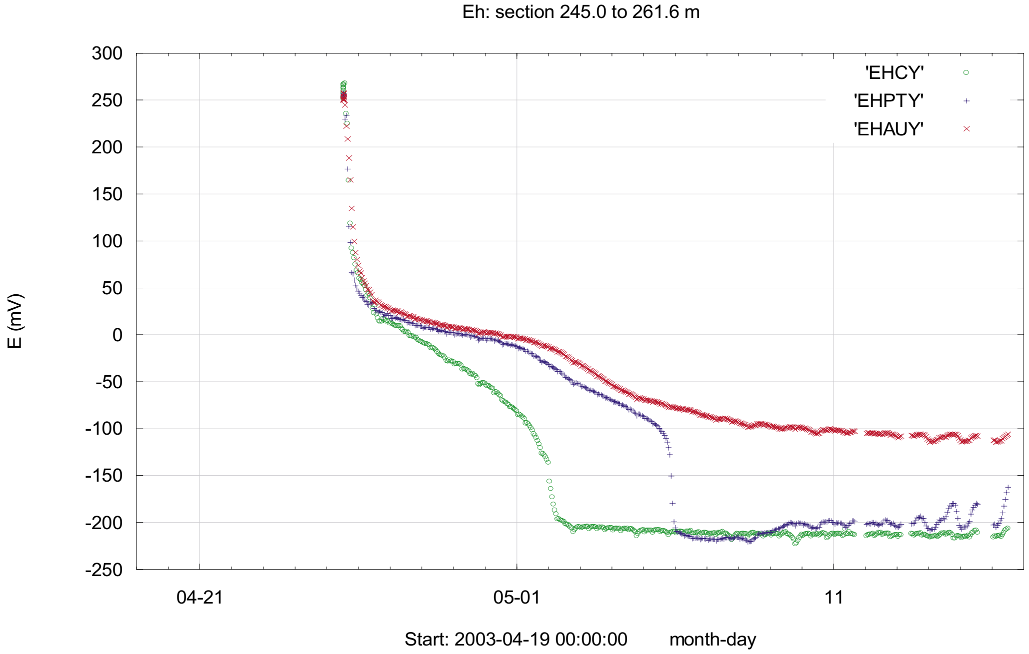


Figure A4-4. Redox potental measurements (Eh) by platinum, gold and glassy carbon electrodes at the surface (EHPTY, EHAUY and EHCY).

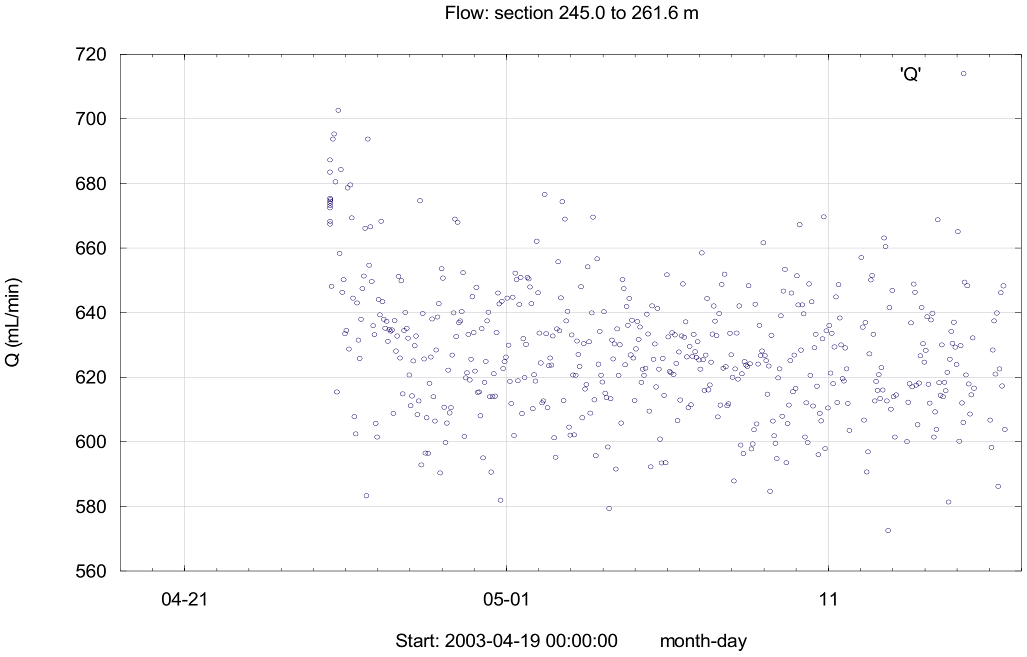


Figure A4-5. *Variation in flow rate during the pumping and measurement period.*

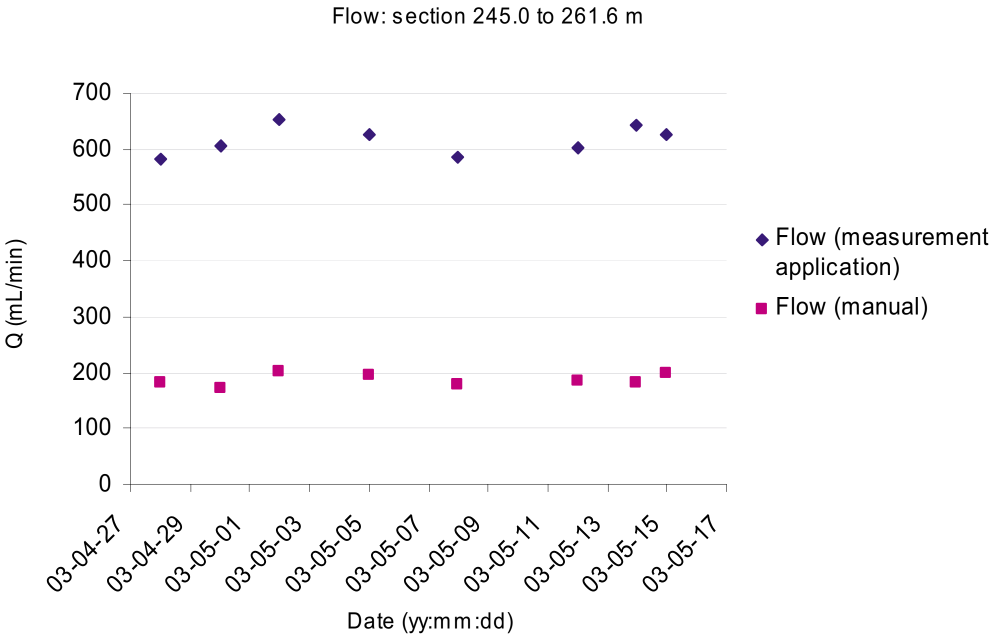


Figure A4-6. *Comparison between flow rate from the measurement application and flow rate from maual measurements.*

Chemmac measurement in section 548.0–565.4 m

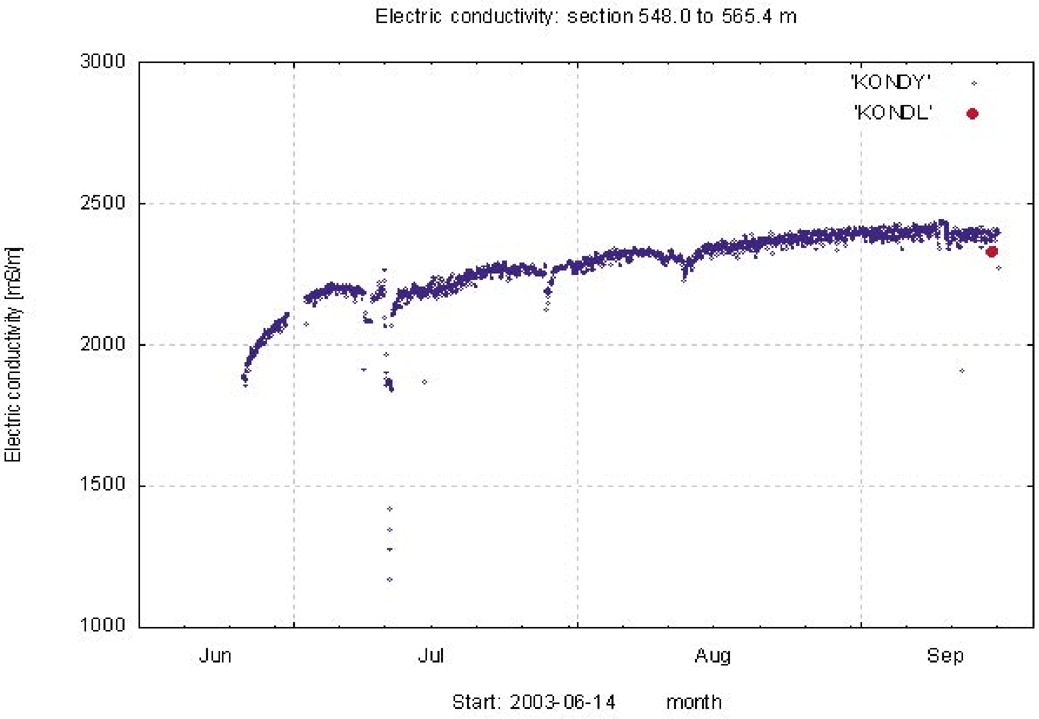


Figure A5-1. *Electric conductivity measurement in the surface measurement cell (KONDY). The electric conductivity measured in the last collected sample (KONDL) is given for comparison.*

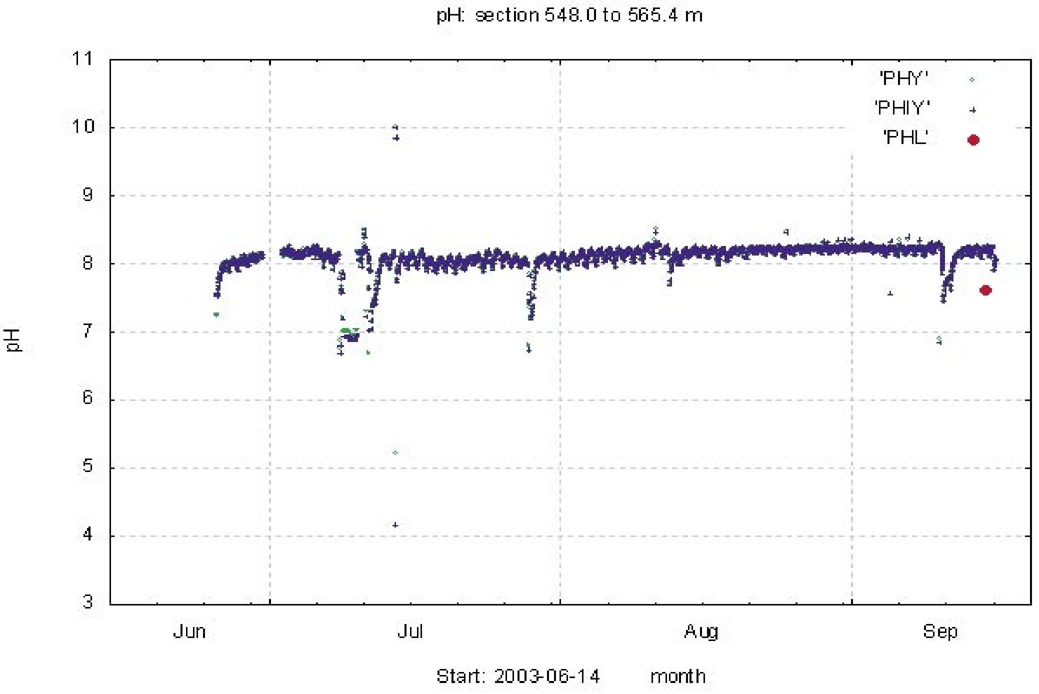


Figure A5-2. *Measurements of pH by two glass electrodes at the surface (PHY and PHIY) The laboratory pH in the last collected sample (PHL) is given for comparison.*

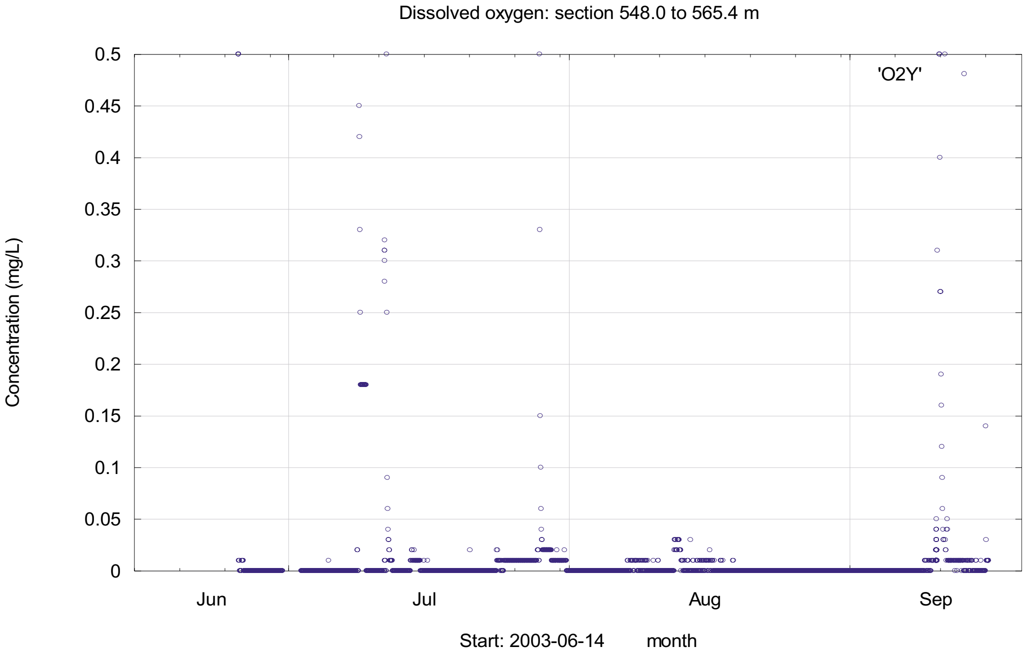


Figure A5-3. Dissolved oxygen measurement (O2Y) in the surface measurement cell.

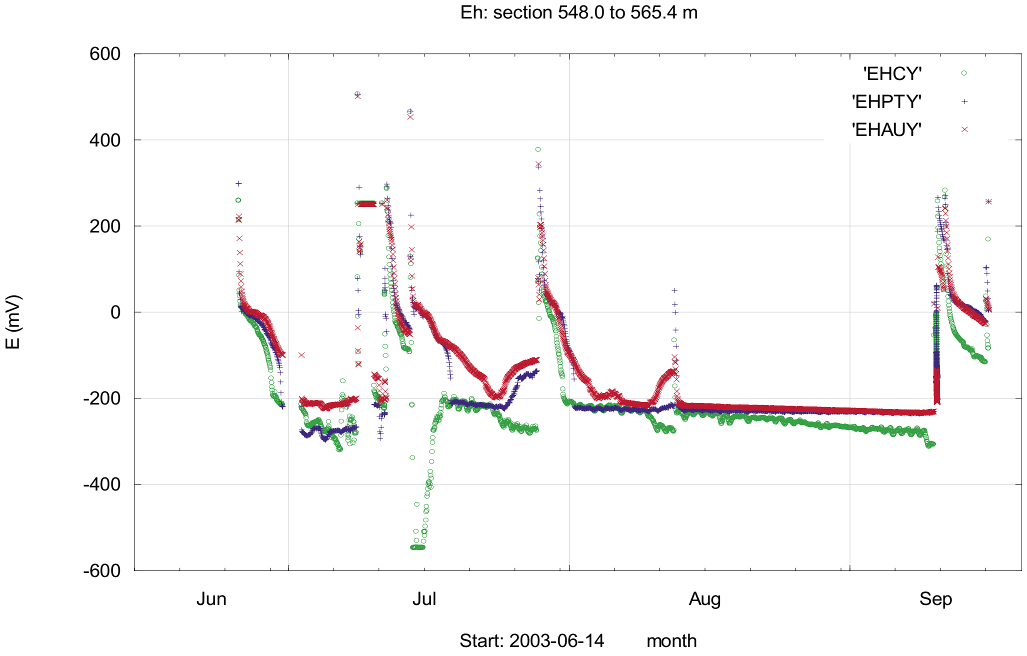


Figure A5-4. *Redox potental measurements (Eh) by platinum, gold and glassy carbon electrodes at the surface (EHPTY, EHAUY and EHCY).*

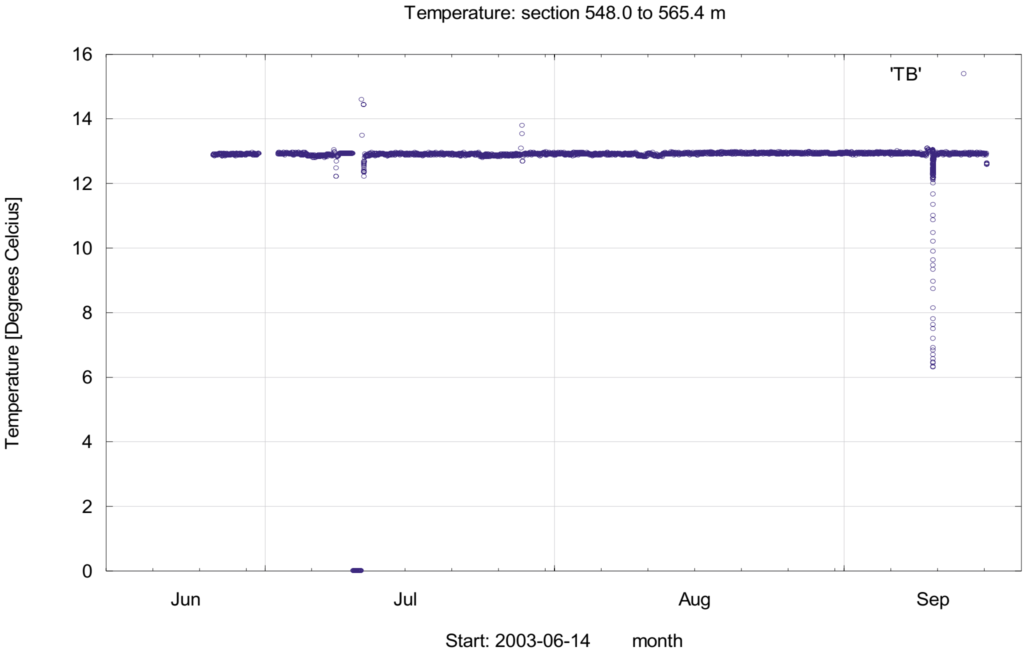


Figure A5-5. *Temperature of the groundwater in the borehole section (TB).*

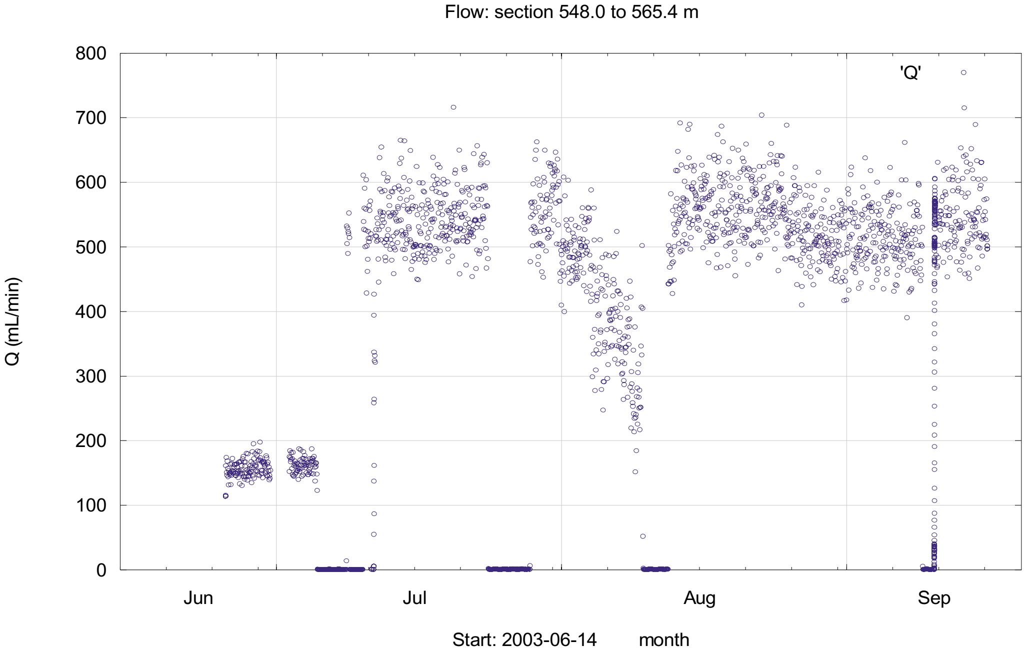


Figure A5-6. *Variation in flow rate during the pumping and measurement period.*

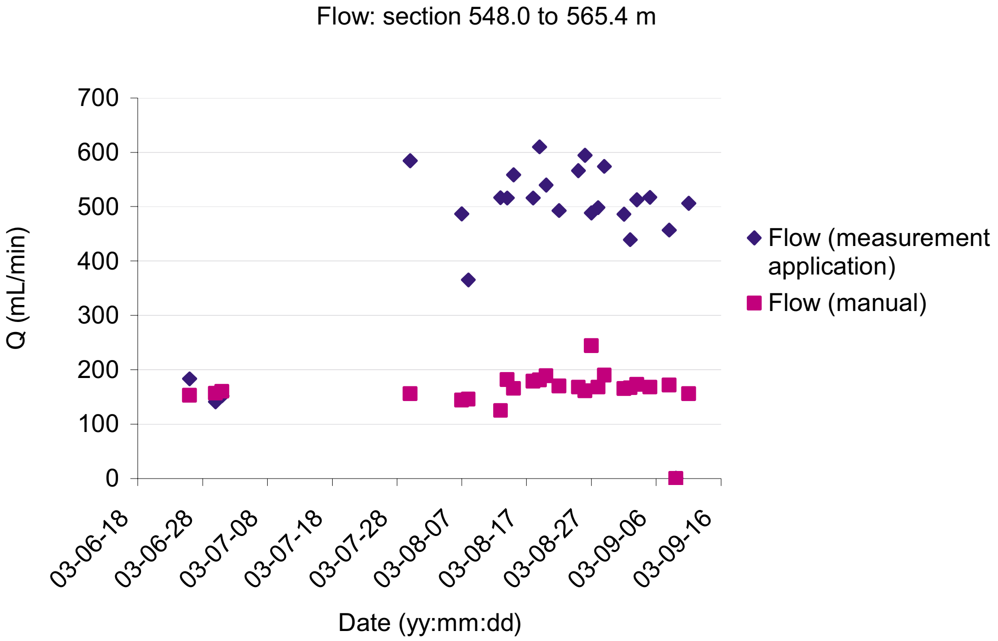


***Figure A5-7.** Comparison between flow rate from the measurement application and flow rate from maual measurements.*

Appendix 6

Water analysis data in SICADA

Table A6-1. Water composition, basic water analysis data.

Idcode	Secup m	Seclow m	Sample no	Charge Bal %	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO^{3} mg/L	Cl mg/L	SO$_4$ mg/L	SO$_4$-S mg/L	Br mg/L	F mg/L	Si mg/L
KSH01A	156.5	167.0	5256		–	–	–	–	69	4,007.1	–	–	–	–	–
KSH01A	156.5	167.0	5257	–2.2	2,090	8.44	915	70.9	30	5,166.4	43.18	14.8	29.56	1.11	3.8
KSH01A	156.5	167.0	5258		–	–	–	–	28	–	–	–	–	–	–
KSH01A	156.5	167.0	5259	–2.4	2,150	9.13	941	70	28	5,333.9	41.68	12.8	33.07	1.23	3.7
KSH01A	156.5	167.0	5260	–1.1	2,300	12.7	975	73.7	26	5,507.6	34.98	13.3	31.22	1.08	3.7
KSH01A	156.5	167.0	5261	–1.0	2,280	12.6	963	71.8	28	5,436.7	35.54	12.8	29.45	0.8	3.6
KSH01A	156.5	167.0	5262	–2.9	2,210	11.3	939	70.4	26	5,489.9	33.58	12.3	31.82	1.22	3.6
KSH01A	156.5	167.0	5263	–2.4	2,280	14.7	960	70.8	25	5,590.1	31.71	12	31.24	0.84	3.4
KSH01A	245.0	261.5	5264		–	–	–	–	19	6,217.6	–	–	–	–	–
KSH01A	245.0	261.5	5265	–3.6	2,450	15.6	1,160	62.4	18	6,342.5	53.19	19.5	35.48	1.2	3.6
KSH01A	245.0	261.5	5266	–1.8	2,580	12	1,160	63.5	18	6,322.2	48.16	18.1	36.14	0.96	3.5
KSH01A	245.0	261.5	5267	–2.0	2,590	13.4	1,140	63.2	17	6,335.5	48.56	17.5	38.43	0.89	3.5
KSH01A	245.0	261.5	5268		2,430	13.2	1,180	65.4	17	6,298.2	51.07	18.3	38.53	1.09	3.8
KSH01A	245.0	261.5	5269	–3.5	2,460	11.6	1,150	64.1	17	6,340.8	49.81	17.7	36.88	0.97	3.7
KSH01A	586.0	597.0	5270		–	–	–	–	18	6,778.6	–	–	–	–	–
KSH01A	548.0	565.0	5271		–	–	–	–	19	7,111.9	–	–	–	–	–
KSH01A	548.0	565.0	5272		–	–	–	–	14	8,100.1	–	–	–	–	–
KSH01A	548.0	565.0	5273		–	–	–	–	14	8,120.5	–	–	–	–	–
KSH01A	548.0	565.0	5274		–	–	–	–	13	8,399.7	–	–	–	–	–
KSH01A	548.0	565.0	5275		–	–	–	–	13	8,392.6	–	–	–	–	–
KSH01A	548.0	565.0	5276		–	–	–	–	12	8,405	–	–	–	–	–
KSH01A	548.0	565.0	5277		–	–	–	–	12	8,423.6	–	–	–	–	–
KSH01A	548.0	565.0	5278		–	–	–	–	12	8,399.7	–	–	–	–	–
KSH01A	548.0	565.0	5279		–	–	–	–	12	8,552.1	–	–	–	–	–
KSH01A	548.0	565.0	5280	–0.3	3,220	12.4	2,190	44.7	12	8,755.1	221.98	73.5	70.95	0.98	4.7
KSH01A	548.0	565.0	5281		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5282		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5283		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5284		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5285		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5286		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5287		–	–	–	–	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5288	–1.3	3,500	77	1,900	47	11	8,875.7	230.48	81	73.19	0.53	4.1

Cont Table A6-1. Water composition, basic water analysis data.

Fe mg/L	Fe-tot mg/L	FeII mg/L	Mn mg/L	Li mg/L	Sr mg/L	pH	DOC mg/L	TOC mg/L	S_2 mg/L	ElCon mS/m	Drill_ water %	I mg/L	NO_2N mg/L	NO_3N mg/L	NO_3N+ NO_2N mg/L	NH_4N mg/L	PO_4P mg/L
–	–	–	–	–	–	7.34	–	–	–	1,181	3.28	–	–	–	–	–	–
1.38	1.604	1.591	0.58	0.303	15	7.51	1.5	–	0.01	1,476	3.7	0.121		0	0	0.08	0.001
–	–	–	–	–	–	7.27	–	–	–	1,513	–	–	–	–	–	–	–
1.15	1.474	1.463	0.56	0.31	15.6	7.43	1.2	1.2	0	1,498	3.34	0.115	0	0	0	0.08	0.001
1.44	1.767	1.743	0.55	0.312	16.8	7.38	1.2		0	1,527	3.17	0.138	0	0	0.001	0.017	0.002
1.38	1.701	1.681	0.54	0.306	16.6	7.38	1	1.1	0	1,484	2.61	0.125	0	0	0	0.083	0.002
1.31	1.596	1.574	0.54	0.302	16.3	7.34	–	–	0.01	1,491	2.51	0.138	0	0	0.001	0.103	0.003
1.15	1.413	1.397	0.54	0.308	15.9	7.36	0.9	0.9	0	1,539	2.39	0.128	0	0	0	0.095	0.004
–	–	–	–	–	–	7.41	–	–	–	1,673	3.6	–	–	–	–	–	–
1.08	1.32	1.34	0.56	0.378	19.7	7.4	<1		0.01	1,739	8.19	0.171	0	0	0	0.097	0.003
1.03	1.325	1.301	0.55	0.369	19	7.4	<1	<1	0.01	1,730	7.54	0.194	0	0	0	0.079	0.003
1.03	1.369	1.34	0.55	0.365	18.7	7.27	<1	–	0.01	1,707	7.48	0.16	0	0	0	0.083	0.003
	1.318	1.296	0.66	0.381	19.6	7.34	<1	<1	0	1,718	8.02	0.192	0	0	0	0.079	0.003
1.05	1.281	1.265	0.56	0.377	19.1	7.36	<1		0.01	1,722	8.22	0.122	0	0	0	0.083	0.003
–	–	–	–	–	–	7.17	–	–	–	1,860	36.58	–	–	–	–	–	–
–	–	–	–	–	–	7.32	–	–	–	1,926	–	–	–	–	–	–	–
–	–	–	–	–	–	6.76	–	–	–	2,105	18.67	–	–	–	–	–	–
–	–	–	–	–	–	7.46	–	–	–	2,167	–	–	–	–	–	–	–
–	–	–	–	–	–	7.51	–	–	–	2,189	17.26	–	–	–	–	–	–
–	–	–	–	–	–	7.48	–	–	–	2,215	17.46	–	–	–	–	–	–
–	–	–	–	–	–	7.14	–	–	–	2,194	15.69	–	–	–	–	–	–
–	–	–	–	–	–	7.16	–	–	–	2,245	15.1	–	–	–	–	–	–
–	–	–	–	–	–	7.38	–	–	–	2,225	15.39	–	–	–	–	–	–
–	–	–	–	–	–	7.32	–	–	–	2,262	13.91	–	–	–	–	–	–
0.638	0.686	0.688	0.46	0.58	32.3	7.45	1.1		0.05	2,275	13.45	0.414	0.001	0	0.001	0.04	0.001
–	–	–	–	–	–	–	–	–	–	–	12.92	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	12.35	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	11.49	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	10.93	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	11.73	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	11.37	–	–	–	–	–	–
0.35	0.523	0.511	0.4	0.88	0.03	7.63	1	–	–	2,325	10.74	–	0.001	0	0.001	0.048	0.001

Table A6-2. Isotopes I, H-, O-, B-, S-, Cl-, C-isotopes and isotope ratios.

Idcode	Secup m	Seclow m	Sample no	∂D dev SMOW	Tr TU	∂^{18}O dev SMOW	^{10}B/^{11}B no unit	∂^{34}S dev CDT	∂^{13}C dev PDB	∂^{37}Cl dev SMOC	^{87}Sr/^{86}Sr no unit	^{14}C pmC	AGE_BP years
KSH01A	156.5	167.0	5256	–88.8	2.6	–12.2	–	–	–	–	–	–	–
KSH01A	156.5	167.0	5257	–95.1	2.8	–12.7	–	–	–	–	–	–	–
KSH01A	156.5	167.0	5259	–93.6	<0.8	–12.9	0.24	21.2	–19.0	0.14	0.71	30.0	9,620
KSH01A	156.5	167.0	5260	–98	0.8	–13	–	–	–	–	–	–	–
KSH01A	156.5	167.0	5261	–97.5	<0.8	–13	–	22.8	–19.1	–	0.72	30.8	9,400
KSH01A	156.5	167.0	5262	–97.8	<0.8	–13	–		–	–	–	–	–
KSH01A	156.5	167.0	5263	–98.2	<0.8	–13.01	0.24	23.1	–13.5	0.31	0.71	–	–
KSH01A	245.0	261.5	5264	–102.2	<0.8	–13.6	–	–	–	–	–	–	–
KSH01A	245.0	261.5	5265	–99.1	<0.8	–13.8	0.24	–	–	–	–	–	–
KSH01A	245.0	261.5	5266	–100.2	<0.8	–13.4	0.24	20.2	–	–	0.71	–	–
KSH01A	245.0	261.5	5267	–99.8	<0.8	–14	–	–	–	–	–	–	–
KSH01A	245.0	261.5	5268	–100	<0.8	–14	0.24	20.5	–	0.65	0.71	–	–
KSH01A	245.0	261.5	5269	–100.6	–	–13.3	–	–	–	–	–	–	–
KSH01A	586.0	597.0	5270	–88.7	2.8	–12	–	–	–	–	–	–	–
KSH01A	548.0	565.0	5280	–91.2	2.0	–12.6	0.24	18.5	–	–	0.72	–	–
KSH01A	548.0	565.0	5288	–92.1	1.1	–12.7	0.22	17.7	–	–	0.72	–	–

Table A6-3. Trace elements.

Idcode	Secup m	Seclow m	Sample no	U ug/L	Th ug/L	Sc ug/L	Rb ug/L	Y ug/L	Zr ug/L	In ug/L	Sb ug/L	Cs ug/L	Ba ug/L	La ug/L
KSH01A	156.5	167.0	5259	0.135	<0.2	<0.5	23.1	1.56	<0.3	<0.5	0.157	1.13	1,280	0.242
KSH01A	156.5	167.0	5261	0.128	<0.2	<0.5	23.3	1.51	0.264	–	0.109	1.16	1,310	0.234
KSH01A	156.5	167.0	5263	0.135	<0.2	<0.5	25.3	0.3	2.35	<0.5	0.135	1.21	1,300	0.507
KSH01A	245.0	261.5	5265	1.01	<0.2	<0.5	29.3	0.311	3.4	<0.5	0.214	1.36	1,380	0.508
KSH01A	245.0	261.5	5266	0.157	<0.2	<0.5	30.5	0.308	2.36	<0.5	0.127	1.34	1,420	0.493
KSH01A	245.0	261.5	5268	0.169	<0.02	0.0338	28	0.115	0.275	<0.5	0.528	1.24	1,530	0.0213
KSH01A	548.0	565.0	5280	0.207	<0.2	<0.5	42.4	0.336	<0.3	<0.5	–	1.39	188	<0.05
KSH01A	548.0	565.0	5288	0.148	<0.2	<0.5	35.1	0.291	<0.25	<0.5	–	1.47	176	0.054

Cont Table A6-3. Trace elements.

Hf ug/L	Tl ug/L	Ce ug/L	Pr ug/L	Nd ug/L	Sm ug/L	Eu ug/L	Gd ug/L	Tb ug/L	Dy ug/L	Ho ug/L	Er ug/L	Tm ug/L
<0.05	<0.3	0.0805	<0.05	1.12	0.0534	1.46	<0.05	<0.5	<0.05	<0.05	<0.05	<0.05
<0.05	<0.3	0.0831	<0.05	0.765	0.0557	1.43	<0.05	<0.5	<0.05	<0.05	<0.05	<0.05
0.503	<0.3	0.906	0.128	0.543	0.082	0.115	0.0681	<0.05	<0.05	<0.05	0.069	<0.05
0.781	<0.3	0.919	0.129	0.54	0.0745	0.116	0.0657	<0.05	<0.05	<0.05	<0.05	<0.05
0.445	<0.3	0.866	0.121	0.486	0.0749	0.121	0.0613	<0.05	<0.05	<0.05	<0.05	<0.05
0.0938	<0.001	0.0087	0.0017	0.0678	0.0072	0.108	0.0037	<0.001	0.0035	<0.001	0.0029	0.0019
<0.05	<0.3	<0.05	<0.05	0.243	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
<0.05	<0.3	<0.05	<0.05	0.095	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Cont Table A6-3. Trace elements.

Yb ug/L	Lu ug/L	Al ug/L	As ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Co ug/L	Hg ug/L	Ni ug/L	Zn ug/L	Pb ug/L	V ug/L	Mo ug/L
<0.05	<0.05	5.6	<1	<0.02	0.57	1.18	0.17	<0.002	1.97	79.70	0.24	0.29	8.38
<0.05	<0.05	5.8	–	<0.02	1.15	<1	0.17	<0.002	2.48	85.10	0.19	0.35	8.59
<0.05	<0.05	22.5	<1	<0.05	0.33	0.75	0.17	<0.002	1.59	82.90	<0.3	0.32	9.57
<0.05	<0.05	<0.7	<1	<0.05	0.66	<0.5	0.25	<0.002	1.75	66.10	<0.3	0.39	10.80
<0.05	<0.05	<0.7	<1	<0.05	0.22	<0.5	0.17	<0.002	1.19	63.20	<0.3	0.37	10.10
0.0349	0.014	4.1	<1	0.03	0.47	<1	0.13	<0.002	1.27	50.40	0.13	<0.05	9.72
<0.05	<0.05	–	–	0.0294	–	–	–	<0.002	–	–	–	0.805	17.1
<0.05	<0.05	–	<2	0.022	–	–	–	<0.002	–	–	–	0.908	–

Table A6-4. Isotopes II, U-, Th-, Ra- and Rn-isotopes.

Idcode	Secup m	Seclow m	Sample no	U-238 mBq/L	U-235 mBq/L	U-234 mBq/L	Th-232 mBq/L	Th-230 mBq/L	Ra-226 Bq/L	Rn-222 Bq/L
KSH01A	156.5	167.0	5259	5,940	240	5,940	<50	110	0.4	44.8
KSH01A	156.5	167.0	5261	110	<50	110	<50	110	1.4	21.4
KSH01A	156.5	167.0	5263	<50	<50	<50	<50	<50	1.4	62.4
KSH01A	245.0	261.5	5266	–	<50	<50	<50	<50	0.6	66.9
KSH01A	245.0	261.5	5268	<50	<50	<50	<50	<50	0.8	73.4
KSH01A	548.0	565.0	5280	<50	<50	<50	<50	<50	0.5	27.3
KSH01A	548.0	565.0	5288	<50	<50	<50	<50	<50	0.6	73.2

Table A6-5. Dissolved gas.

Idcode	Secup m	Seclow m	Sample no	Ar mL/L	He mL/L	N_2 mL/L	CO_2 mL/L	CH_4 mL/L	O_2 mL/L	H_2 µL/L	CO µL/L	C_2H_6 µL/L	C_2H_4 µL/L	C_2H_2 µL/L	C_3H_8 µL/L	DISS_GAS mL/L H2O
KSH01A	156.5	167.0	5263	1.28	2.2	75.5	0.79	0.06	0.9	<3.4	<4.2	1	0.23	0.1	1.4	79.8
KSH01A	245.0	261.5	5269	1.1	1.5	104	0.8	0.09	23	85	<11	0.88	0.93	<0.1	2.5	107
KSH01A	548.0	565.0	5288	1.4	7.5	67.2	0.08	0.04	0.17	81	<3.9	0.7	0.71	0.35	1.7	76.4